THE TECH ENGINEERING NEWS

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Number 6

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The loss of recoverable alloys in steel scrap has been a major problem confronting the various conservation agencies. Proper segregation of scrap is one effective answer.

Segregation of scrap at the source is comparatively simple. The difficulty comes in preventing mix-ups in subsequent handlings. They can be prevented or remedied by applying two simple tests—spark and spot.

The presence of molybdenum, or nickel, or both, is readily detected by spark testing. Molybdenum causes an easily recognized secondary burst at the end of the spark stream resembling a spearpoint. Nickel produces a spot of intensely white light in the stream near the grinding wheel.

Both elements have a tendency, in the higher contents, to suppress the supplemental bursts characteristic of carbon steels.

Several spot tests for molybdenum have been developed. The simpler ones depend on the red color produced by either potassium ethyl xanthogenate or sodium thiocyanate added to a molybdate obtained from the etched surface of the steel. The dimethyl glyoxime test for nickel also depends on a red coloration. Many of these tests are approximately quantitative.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

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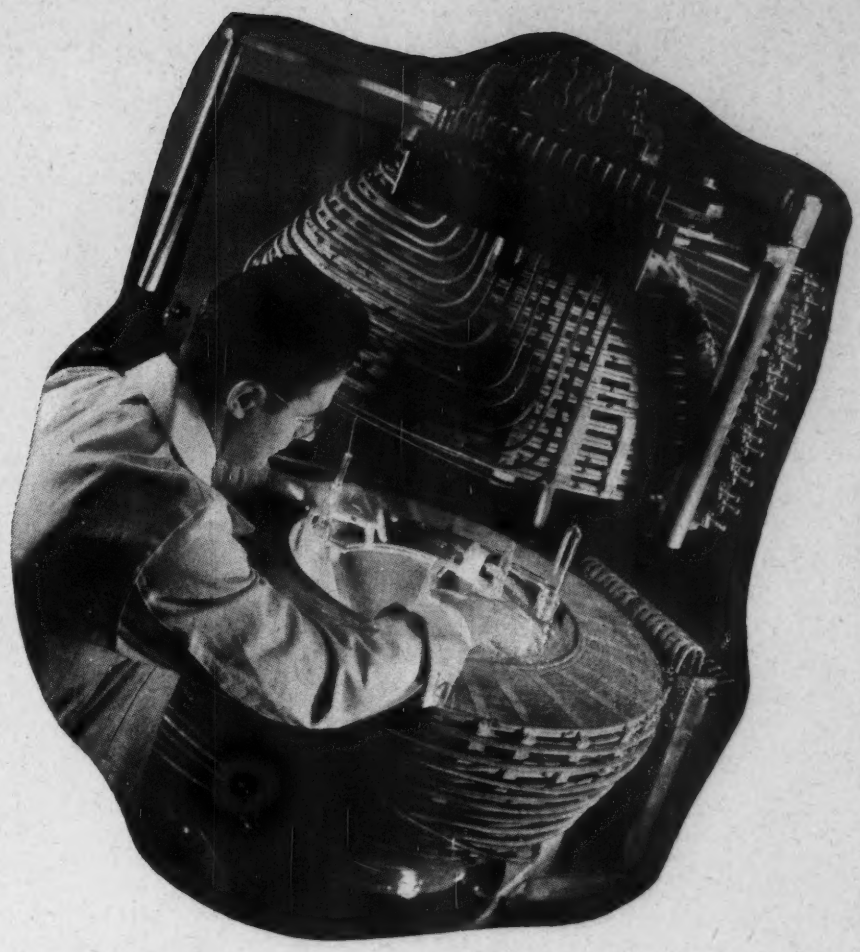
HIGH LIFE IS HARD on carbon generator brushes in high-flying bombers. They used to wear down to the pigtails in an hour or two, at 30,000 feet. Now Westinghouse engineers have developed a chemical treatment that keeps the brush face lubricated at substratosphere heights. Result: *fifty-fold* increase in brush life . . . enough for a dozen raids over Berlin.

EVER SEE A MILLIONTH of an inch? Probably you never will—but the Electrigage can *feel* as little as twelve millionths. Developed by Westinghouse and Sheffield Corporation, it can measure with a precision equal to finding an error of three-quarters of an inch in a mile. Infinitesimal movement of gauging stylus induces a tiny current, which is amplified 10,000 times.

AIR IS HEAVY STUFF when you start pushing it around at 400 miles an hour. That's why U. S. Army needed a 40,000 horsepower electric motor to create a man-made hurricane, for testing airplanes in Wright Field wind tunnel. It is the world's largest wound-rotor induction motor, designed and built by Westinghouse engineers.

• • •

The above items are condensed excerpts from articles in the WESTINGHOUSE ENGINEER, a bi-monthly engineering review. Regular subscription price—$2.00 a year. *Special price to students—50¢.*



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The mass spectrometer provides a new way to get the quick, accurate analyses that are needed to maintain precise process control. Take the synthetic rubber industry, for example. Formerly, five men took as long as three days to complete necessary chemical tests in the processing of artificial rubber—which meant that the results were often too late to be useful.

The new electronic "chemist," the Westinghouse mass spectrometer, now makes these tests in about 15 minutes.

For leadership in the electrical solution of industry's problems, look to Westinghouse. *Westinghouse Electric & Manufacturing Company, Pittsburgh 30, Pennsylvania.*

Tune in John Charles Thomas, NBC, Sundays, 2:30 p.m., E.W.T.

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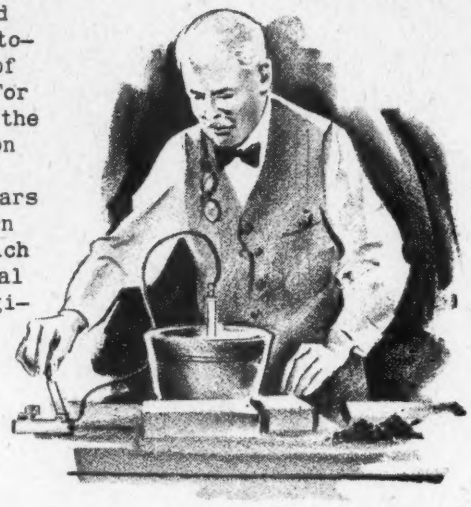
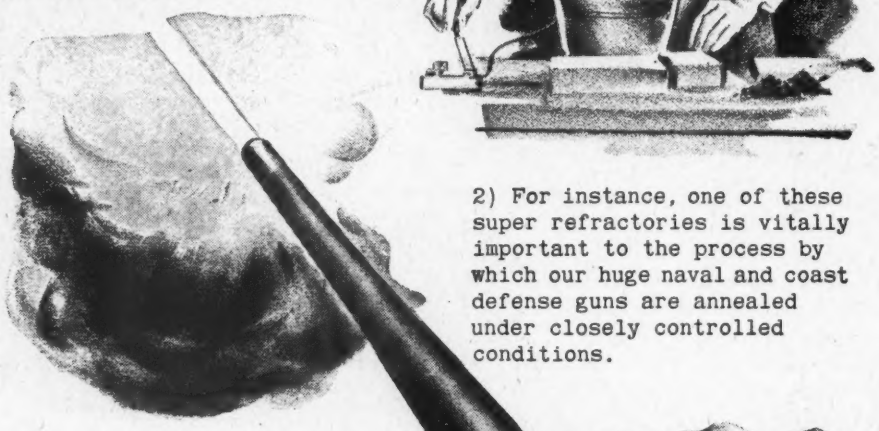
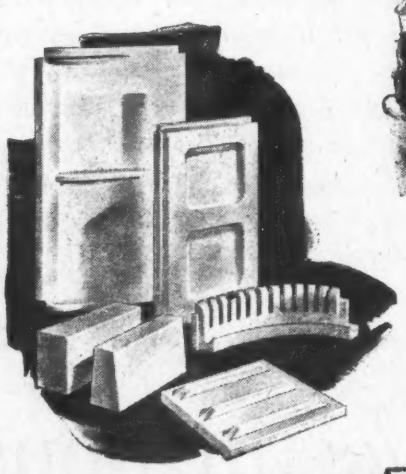
1) This little iron bowl helped shape the pattern of industry today; it holds the key to much of the progress that is to come. For in it Dr. E. G. Acheson created the first man-made abrasive, silicon carbide, to which he gave the trade name "Carborundum"—52 years ago. From that discovery in turn came the super refractories which opened the way for the economical development of modern metallurgical processes.





2) For instance, one of these super refractories is vitally important to the process by which our huge naval and coast defense guns are annealed under closely controlled conditions.

3) To withstand other specific service needs covering a wide range of conditions over 65 varieties of Carborundum Brand Specialized Refractories are available. Used in furnaces, kilns, retorts and refining equipment, they are helping to speed output of thousands of war essentials.



4) After the war, these super refractories will help produce new and better materials. When you encounter a refractory problem in the field, remember Carborundum Refractory Specialists stand ready to help you solve it. The Carborundum Company, Perth Amboy, New Jersey.

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No after-the-war prospect is brighter than that of railroad travel. It requires little imagination to see vast fleets of gleaming, streamlined trains, carrying immense numbers of passengers in safety and comfort. The innate American desire "to go places" can then be gratified with luxury and speed.

This confidence is based on the proved success of an idea. For seven years before the war, the Budd idea of lightweight stainless steel trains, designed to make coach travel attractive by day and by night, as well as economical, was thoroughly tested by one railroad after another. In no instance did it fail to win greatly increased patronage by the public.

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That was the last passenger equipment to be built. Budd plants and Budd workmen, trained to ideas and steel, have been employed day and night in producing planes, naval structures and armament.

When the war is over, the railroads of America, free from war's emergencies, free to use fully their resources and enterprise, will enter upon a brilliant new era of public transportation.

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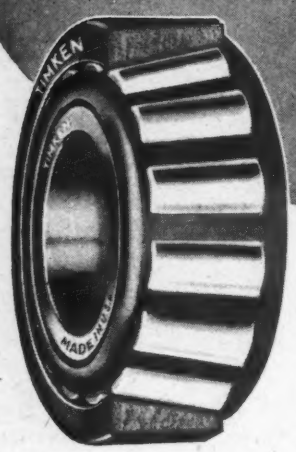

THE new world —the world of the post-war era — will be a world of wheels to a greater extent than ever before. The development of new kinds of production and transportation equipment, and the recreation of existing machines will greatly increase the necessity for and importance of bearings capable of meeting new conditions of speed, precision, load capacity and endurance.

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THE TECH ENGINEERING NEWS

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Insulators Under Fire. Testing to assure that the porcelains will withstand the specified voltages before permitting arcs, and also that flash-overs as shown here leave no impairment of dielectric qualities.

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THIS IS M. I. T.

THE CO-OPERATIVE COURSE IN ELECTRICAL ENGINEERING

By PROFESSOR WILLIAM H. TIMBIE

Professor of Electrical Engineering and Industrial Practice

A BODY of loyal alumni, informed up to the minute concerning the activities of their Alma Mater, is the most valuable asset any educational institution can have. But the Institute is conducting educational work in a multitude of rapidly changing and broadening fields, and its graduates are scattered over the whole face of the earth. Under these conditions, the task of keeping its alumni currently informed is increasingly difficult — so much so, that information on even some of the fundamental educational policies takes a long time to seep down through the alumni body.

An outstanding example of this is the question which keeps cropping up concerning the research activity at the Institute, "Is not this increasing interest in research and in the training of expert investigators likely to crowd out the undergraduate education of engineers?" This in spite of the oft repeated announcement of our educational philosophy, which states in the clearest terms that, "important as are the practical accomplishments of our research program, its chief value in peace times is educational — the inspiration it gives year after year to thousands of undergraduates working side by side with talented scholars who are engaged in pushing out the boundaries of human knowledge." This fact has been stated repeatedly, and yet the question crops up perennially.

In the same category are the Co-operative Courses. The Co-operative Course in Electrical Engineering, VI-A, is now completing its twenty-fifth year of continuous operation, and the question is still asked — "What is the Institute doing to enable students to link up their theory with current engineering practice, and to keep them up to date on constantly changing industrial conditions?" The T.E.N. has characteristically offered us space to explain more fully than is possible in the Institute catalogue, how the Co-operative Course meets this educational need.

In its earliest days, M. I. T. recognized that however well grounded in theory a technical graduate might be, he could not tackle effectively the engineering problems of industry until he had also become familiar with current industrial practice. Accordingly, its graduates have never been given an engineering degree, but merely a degree in Science. Upon graduation a student usually entered an industrial organization as an apprentice. During this period the student's engineering training lay more or less dormant, and much of it was forgotten. As an engineer would say, there was too much slack and lost motion in the arrangement. It was evident that a student ought to be getting his undergraduate practical experience while acquiring his undergraduate theoretical education. The first attempt to combine the two was to transplant into the engineering schools representative specimens of industrial equipment and even of industrial production.

This policy was found to have several defects:

(1) The initial financial outlay was extremely high if anything further than the fundamental shops were to be equipped.

(2) In a rapidly expanding industrial era the cost of keeping machines and processes up to date was prohibitive.

(3) It was necessary either to abbreviate greatly the theoretical content of the curriculum or to lengthen the time which the student would be required to spend in school.

Hence the problem boils down thus:

A young man goes to an engineering school solely for the purpose of acquiring the scientific habit of thought and knowledge of the principles and theories underlying modern industrial problems, because it is extremely difficult for him to acquire these while he is employed in industry. However, one of the fundamental principles of the process of learning, almost as universal a principle as the law of gravitation, is that no one can thoroughly grasp the meaning of an abstract theory until after he has had concrete experiences in its application. If the school takes the time to afford the student these necessary experiences, he must either go without much of the very education for which he came to the school or must remain in school a considerably longer time. It looked very much as though the embryo engineer just had to have his educational cake and eat it too.

One of the most successful solutions of this dilemma is the co-operative plan. In 1919 Professor D. C. Jackson, at that time head of the Electrical Engineering Department, and Mr. E. W. Rice, Manager of the Lynn Works of the General Electrical Company, worked out and put into operation the main features of the present Co-operative Course in Electrical Engineering, VI-A.

In the twenty-five years since its inception practical operating difficulties have been worked out, and at the present time a highly effective plan of operation has been developed.

In the first place — and this point is fundamental — the co-operating companies recognize that industry shares an equal responsibility with the engineering schools in educating and training the recruits to its engineering force. Hence M. I. T. Co-operative Course in Electrical Engineering is not of the earn-while-you-learn variety. To be sure, the students earn wages and are paid wages, but the money earned is a mere by-product of the plan. Each detail has been worked out entirely on the educational principle of making each period of the greatest possible educational value in preparing the students to understand clearly the industrial problems of their own era and equipping them to contribute to the solution of these problems.

Much consideration was given to the detail of the length of the coöperating periods. If they are too short, a student cannot undertake a job of major importance, because such a job usually requires several months for completion. If the periods are too long, the student remains away from school so long that he gets out of the habit of study and loses considerable time in taking up the slack. The Co-operative Courses in Electrical Engineering at Technology have standardized the "term-on, term-off" schedule for the following reasons:

(1) To make the periods spent at the Institute coincide with the regular Institute terms. The student thus becomes a part of the regular student body and is afforded an opportunity to enter into the regular campus activities. Experience has shown that the percentage of coöperative students engaged in important extracurricular activities is as high as that of students in the non-co-operative courses.

(2) To afford a four-month work period, which enables the student to be put on important work projects and to advance through the various stages of responsibility connected with them. On special assignments the period may be lengthened to eight months.

The student's habit of study is maintained while he is at work by his having to carry on regular classwork in the engineering subject which he would have been pursuing had he remained at the Institute. In general, the non-resident courses are conducted by engineers of the co-operating companies and have proved unusually effective. These instructors not only know the theory of the subject but also are able to point out numerous recent applications that are being carried on in the local plant right under the student's eyes. With two evenings each week taken up by recitations and two evenings taken up by preparation, the student keeps up his study habits and still has three evenings a week for recreation. An experience of twenty years has proved that periods of intense mental activity alternated with periods of less intense study are surprisingly effective in developing mental powers, just as periods of intense physical exercise alternating with periods of lighter exercise (not complete rest) have proved the most effective routine for producing maximum physical fitness. This result is to be expected, and it is a matter of fact that toward the end of a term spent in intense study at the Institute, the student begins to look forward to the practical work at the plant. And after a term spent at the plant, he is as anxious to get back to his studies at the Institute. Fortunately good habits are as hard to break as bad ones, and experience has shown that the graduates of VI-A continue this good habit of evening study long after graduation. This study may consist of problems coming up in their daily work, or engineering courses of an advanced nature. This is probably one of the strong contributing factors to the rapid promotion of many of its graduates. This substantiates that all-too-frequently forgotten dictum of a former great industrialist —

> "For the work you do in my plant during the day, I pay you.
> For the study you do at home evenings, I promote you."

One outstanding need of American industry is for off-standard engineers. Industry does not want its engineers to be human bricks, just so long, so wide, and so high. All engineers must of course be trained to think with the same rigor. All must be thoroughly grounded in the same fundamental mathematics, physics, and economics. But, in addition, industry desires that each engineer should have some particular field in which he shows a marked aptitude and in which he has more than the usual knowledge common to all graduates. The Institute's Co-operative Courses, containing as they do the same basic scientific and economic principles and differing only in the specific applications of these principles, easily meet the first two requirements. And they go farther, because of the realization that arrangements must be made sufficiently elastic to meet the need of the individual student. In all save the basic subjects, therefore, substitutions are not only allowed but encouraged. This provision does not mean that a student can scatter all over the lot, but rather that in the later years of his course, he is encouraged to select his subjects of study for the purpose of arriving at some particular goal in some particular field where he is ambitious to work and for which his natural aptitudes fit him. Obviously, the extent to which such a policy can be pursued is limited by the size of the school and the number of subjects it can offer.

This same educational principle is applied to the work at the plants. A plan of co-ordinated practice and study has been worked out in which the engineering practice constitutes regular courses, just as carefully laid out and supervised as the course of study at the Institute. However, just as at the Institute no two students need be taking exactly the same studies, so at the plant no two students need be working on just the same project. A group of projects is first laid out of which each student takes a number sufficient to insure that each acquires an adequate knowledge of fundamental operations. Later the individual student is assigned to those special projects which will advance him most surely and quickly toward the goal at which he is aiming. The projects which make up a student's practical experience are arranged in rising order of importance and difficulty, each assignment carrying with it increased responsibility.

In order to establish and maintain proper co-ordination of studies and practice and to insure that the practice proceeds by steps requiring increasing technical knowledge and skill and more responsibility on the student's part, the student receives his industrial experience in the plants of one company only. Each company must therefore be of a size sufficient to offer the student a comprehensive experience in his chosen field. An added advantage of this arrangement is that a young engineer comes to understand the company's policy and gets acquainted with the personnel. Thus he acquires a certain company loyalty — an all-important quality in the education of any young man.

Expressed in educational vernacular, the educational value of the intimate contact that the student has with

(*Continued on page 206*)

CYCLES, CODES, AND COPIES

PART I

By J. O. PERRINE

Assistant Vice-President American Telephone and Telegraph Company

Dr. J. O. Perrine, although not an alumnus of the Institute, has been closely connected to it throughout his career. He has taught for the M.I.T. VI-A Electrical Engineering Coöperative Course, and has written several articles for T.E.N.

Dr. Perrine received his Master's degree at the University of Michigan in 1909, after having studied physics, mathematics and chemistry at the University of Iowa. In 1921 he received the Doctor's degree in Physics at Cornell.

During the first World War he gave one of the first courses to be offered in an American technical school in electronics and high-frequency phenomena at Pennsylvania State. Subsequently as a Captain in the Army he was in charge of the Signal Officers Candidate School at Yale. He entered the employ of American Telephone and Telegraph in 1921 in the Department of Development and Research, later becoming Editor of the "Bell System Technical Journal."

Dr. Perrine has given many lecture-demonstrations in communication to engineering societies throughout the United States and Canada, including addresses to various branches of the M. I. T. Alumni Association.

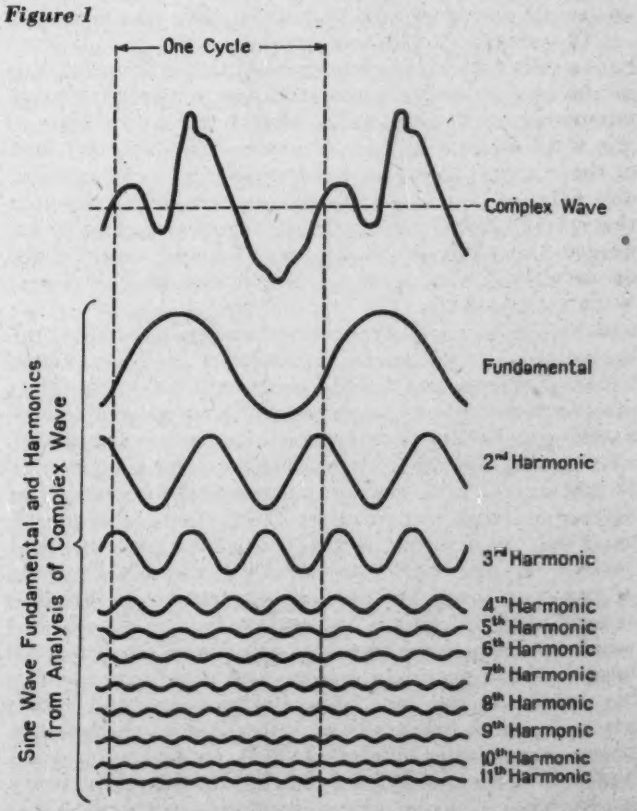
ALL communication systems make use of waves. Aside from the senses of touch, taste and smell, all we learn, all we understand, all we receive in various kinds of communication systems, including the printed word, come to us either through our ears or our eyes. For centuries, sound and light waves were the only methods of signaling. Gesture, a sort of visual signaling greatly used today, probably antedated actual speech. During the last century electric waves became available for signaling. Just about one hundred years ago, Morse perfected the telegraph which used electric waves guided by metallic wires to transmit a substitute for words. The telephone was a significant advance since it transmitted speech itself. Then unguided electric waves, now called radio waves, became facile bearers of messages. In general, messages may be a code or a copy; a substitute or a facsimile; a gesture or a spoken word; a telegraph current or a telephone current.

The development of visual signaling and wire radio telegraphy and telephony has been rapid. The most common method of communication, namely, human speech, has utilized sound waves; but except for use as face-to-face speech, sound waves have not been used in any great degree as a practical method for signaling. Sirens, whistles, bells, all emit sound waves; but it is a fair statement that in general sound waves as a means of code signaling have not been used as extensively as other kinds of waves.

Complexity of Waves Controls Quality

In considering the transmission of information by waves, it is important to appreciate that the quantity of information, Q, borne by waves is a function of two variables. Frequency band or range of frequency is one

Figure 1

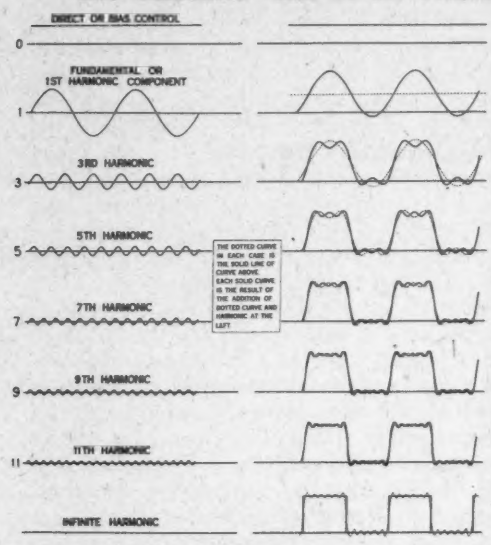


ANALYSIS OF SOUND WAVE BY FOURIER'S THEOREM

variable and the time, T, available for the transmission of the message is the other variable. This period of time is not the time involved in the sheer velocity of the wave through the medium, but the period of time needed by the apparatus and circuit in getting the message through. A simple equation gives the relation of the factors involved:

$$Q = KT(f_1 - f_2)$$

The numerical value of the constant, K, is ever likely to increase as new theories, apparatus and operating techniques are developed.



COMPOSITION OF SQUARE-TOPPED WAVE
Figure 2

It is therefore a simple idea, but a very basically important idea that information can be transmitted only by a change in a wave, *i.e.*, a change in frequency. A change in a wave gives quality or character to that wave and to the message borne by the wave. Quality and the power with which the wave train is projected are the most important features of waves. One may have a sound wave, a light wave, or a radio wave, but if there is no change in these waves there is no information borne by it. Perhaps the simplest change is to turn a wave off and on. A light is turned off and on, an electric telegraph current is made and broken, a sound wave is started and stopped.

In the case of signaling with all forms of waves, one could, besides starting and stopping the sound, change the power or the pitch or the quality to convey information. However, changes in power cannot be effected without a change in frequency appearing as a transient. Actually, of course, in the whole scheme of things it is generally better to change the quality, that is, to use waves whose quality results from a broad array of different frequencies, each of which embodies different amounts of power.

Obviously, the more possible changes of quality, the more information can be transmitted. So to state the fact more completely that "practically all communication systems make use of waves" it is appropriate to state "practically all communication systems make use of a *group* or *range* of waves." The wider the range of waves available, obviously the greater the possibility of change and a greater quantity of information conveyed. So if one has a tuning fork of a single frequency, about all one can do is stop and start — not much change to transmit a great amount of information in a given length of time. But if, as in human speech, one has available frequencies from 50 cycles per second to 8,000 cycles per second, then a great deal of information can be sent in a given time. Therefore we come to the fact that in communication systems through the years a strenuous attempt has been made to achieve a wider range, a wider band of frequencies. A pure tone, like a tuning fork or even a human whistle which does not have many component frequencies continuously radiated as such, bears very little information. To be really communicative, a sound wave must be a composite wave, a multiform wave, an ensemble of waves; it must have quality. With different quality, a sound wave conveys a great deal of information; human voices identify many different persons; flutes are flutes; saxophones are saxophones; hisses are hisses; drums are drums; crashes are crashes.

So really effective sound waves are complex waves. In the accompanying drawings, Figures 1 and 2, it is shown how an irregularly shaped wave is actually made up of a number of regularly shaped waves. The number of the separate waves, their individual amplitudes and their individual frequencies make for different complexity and for different quality. It is a surprising fact that no matter how irregular in shape or how odd in tone quality a sound may seem to be, it can always be thought of as composed of a group, a range of regularly shaped waves or so-called pure tones, a sort of family of pure waves.

Harmonics, Odd and Even

The curves of Figures 3–6 illustrate the formation of an irregular wave by the addition of a fundamental wave and a single harmonic wave. The fundamental wave is that of a "pure" tone or sine wave as emitted by a tuning fork. The fundamental wave is also called the first harmonic since it is the first harmonic component of the resultant complex wave which, in this case, does not become very complex. The various harmonics are also assumed to be "pure" waves as might be produced by tuning forks with the appropriate higher pitches. Harmonics may have frequencies which are a whole number multiple of the fundamental or a fractional part of a whole number multiple. That complex sound whose array of harmonics is whole number multiples will have tone quality such as a human voice and most musical instruments like the flute, clarinet, trombone and cello. That complex sound whose harmonics are fractional parts of whole number multiples will be noise, of which there are many kinds. Sometimes noises such as anvils, snare drums and cymbals are used in orchestral music.

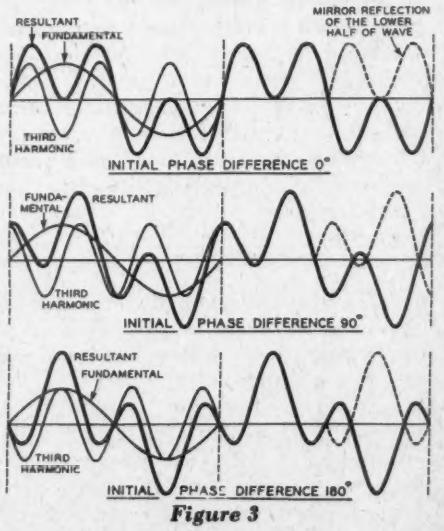


Figure 3

It will be observed from the curves of Figures 3 and 4 that the addition of the third harmonic to the fundamental results in a wave which is itself symmetrical. It will be observed that, in this case, the second half of a complete wave is just the converse or mirror image of the first half. In Figures 3 and 4 the second half of the second wave has been rotated around the axis line of the wave and made into a dotted line above. This dotted line half wave appears as it would if looked at in a mirror. The important point is that the mir-

rored second half is exactly the same shape as the first half. Therefore, however complex a wave is, the second half of that complex wave will look like the first half provided the one or the several harmonics are odd multiples.

When the harmonic added is the second harmonic, namely, an even harmonic, then the second half of the complex wave will not look like the first half as shown in Figures 5 and 6. The complex wave is not symmetrical when the harmonics are the second, fourth, sixth, etc.

Furthermore, Figures 3–6 illustrate the fact that while symmetry or non-symmetry gives information as to whether the harmonics are odd or even, the actual shape and appearance of a complex wave, as for example on an oscilloscope screen, also gives information to a trained observer as to the relative magnitude of the amplitude and phase of the harmonic compared to the fundamental. The upper left parts of the two third harmonic charts, Figures 3 and 4, where phase difference is 0°, are not exactly alike but would seem, even to an inexperienced observer, to be the same type. In other words, different relative amplitudes do not greatly alter the general shape of a complex wave provided the components are in phase.

A simple and common term used in connection with the relations of several waves is "phase." In the drawings of all of the complex waves, it will be observed in some cases the component waves all start out in phase. In other cases, the several waves start out in different phase, 90°, 180° and 270°.

In any one of the group of curves, phase difference makes a difference in the general shape of the curve. The resultant in upper left and lower left of Figure 4 presents quite a contrast in shape. This difference in shape as seen on an oscilloscope is apparent. However, the surprising fact is that phase difference of components makes practically no difference in the sound of these tones when heard by the human ear. The complex sounds look different but sound the same. This fact is common experience. The blending of several instruments or voices is not affected by the possible tiny fractions of seconds of difference at which the component tones come in.

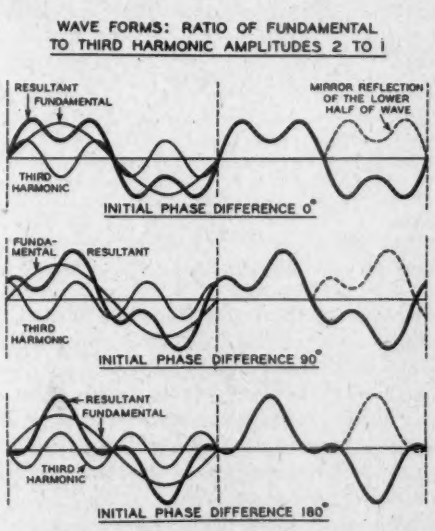


Figure 4

Harmonic and Non-Harmonic Waves

In considering quality of waves and their composite nature, one immediately is concerned with the two fundamentally different kinds of complex waves. These two are:

1. Harmonic sounds — vowels and most musical tones.
2. Non-harmonic sounds — noise.

In harmonic sounds like speech and music, the various component waves (overtones) have frequencies which are simple arithmetically progressive multiples of the fundamental tone. In the accompanying chart, the fundamental has a frequency of, say, 100 vibrations per second. The overtones have frequencies which are twice, thrice, four times, seven times, ten times, and so on. So the vocal chord sound of a human throat is composite sound. The fundamental is about 125 cycles per second for men, with harmonics or overtones up to at least 4,000. By varying the harmonic relations of the overtones or composite frequencies and of course the amount of power in these overtones, different vowel sounds are made. Individual voices vary in their quality; different musical unstruments vary in their quality, too. Oboes, violins, trombones, flutes, pianos — all have different "voices," different harmonically related wave patterns. By their variations in quality, as a particular musical "voice," they convey information as to who is playing. By further variations, one after another, voices make speech sounds and words. The greater the variation in wave composition, the greater the amount of information conveyed.

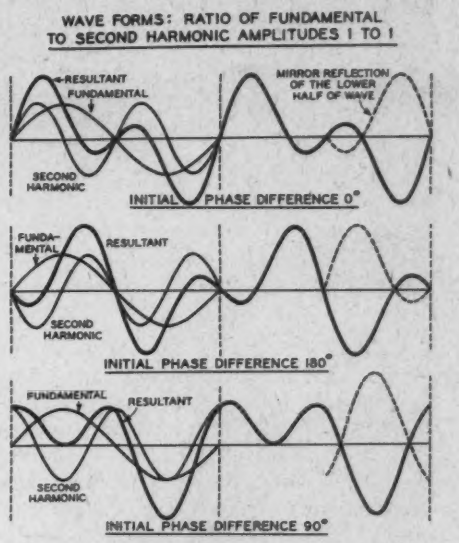


Figure 5

Printed Words Versus Spoken Words

Waves or vibrations or cycles are the stuff of which information is made. Frequency band has become a commodity to the communication engineer. With various frequency bands he transmits facsimile speech, music, code signals as in telegraphy, still pictures and moving pictures.

The electrical transmission of printed words does not need as wide a frequency band as spoken words. Oral speech possesses inflection, naturalness and niceties of tone which are definite aspects of information and which demand an adequate frequency range. Spoken words possessing the same articulation, crispness and understandability can be made to convey entirely different meanings by variation in emphasis and inflection. The same words may be used to convey joy or sadness, friendliness or dislike, enthusiasm or indifference. These latter require their complements of waves. Telegraph systems transmit 75 words per minute by using a frequency range of about 200 cycles per second. Telephone systems carrying these same words would convey more information and generally use a range of about 3,000 cycles per second. The first telephone circuit across the United States transmitted no frequencies below 500 cycles per second and none above 1,400, a range of only 900 cycles per second. Today, transcontinental wire lines and transoceanic radio telephone systems possess frequency ranges of about 3,000 cycles. Special radio broadcasting network telephone lines transmit a range of 5,000 cycles and even up to 8,000.

(*Continued on page 204*)

BUILDING A MODERN SUBWAY

By CURT B. BECK

Editor-in-Chief, Tech Engineering News

OF all the branches of technology, there are few more important or interesting than construction, for it is in homes built by engineers that we work, play, and live. So when the construction takes place underground, and stretches for several miles, a feat of engineering must take place which staggers the human mind. Such a project was the recently completed Chicago Subway.

The Chicago Clybourn-Division-State Street Subway, a five-mile route opened for revenue in October 1943, is an excellent example of modern subway construction technique. This subway route, the most recent of its type to be built, was started in December 1938 and completed in 1943 at a cost of nearly $34,000,000 and was financed jointly by the City of Chicago and the FWA. Soon after plans for its construction were drawn up it was declared a defense project and now is carrying an average of 80,000,000 riders a year, 10,000,000 passengers in excess of optimistic advance estimates.

The first step in this undertaking, as is the first step in any subway construction project, was the planning. Engineers, designers, draftsmen and detailers worked twelve, even fourteen hours a day, seven days a week, for several months. Field surveys and soil tests had to be conducted, general policies of design had to be drawn up, and contracts had to be awarded. It was decided to build the structure in sections. Tunnels, cross-overs, mezzanine sections, river crossing and auxiliary structures all had to be provided for, and suitable tables of design specifications had to be prepared and issued to designers. A partial list of typical loads which had to be considered is given below:

Loads

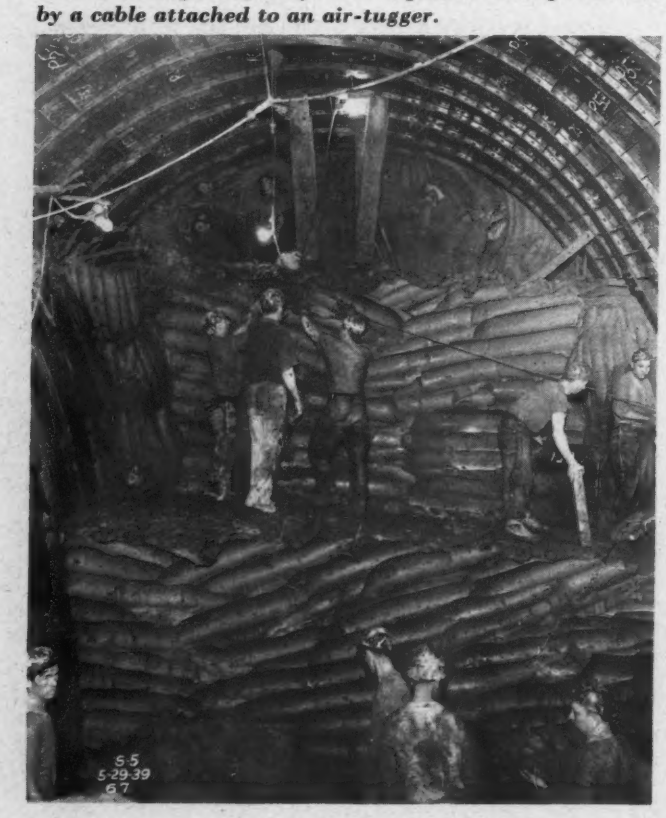
Weight of pavement	150 lbs. per cubic foot
Weight of soil above +5, C. C. D.*	100 lbs. per cubic foot
Weight of soil below +C. C. D.*	120 lbs. per cubic foot
Live loads on sidewalks	200 lbs. per square foot
Live loads on platforms, stairs, ramps	150 lbs. per square foot

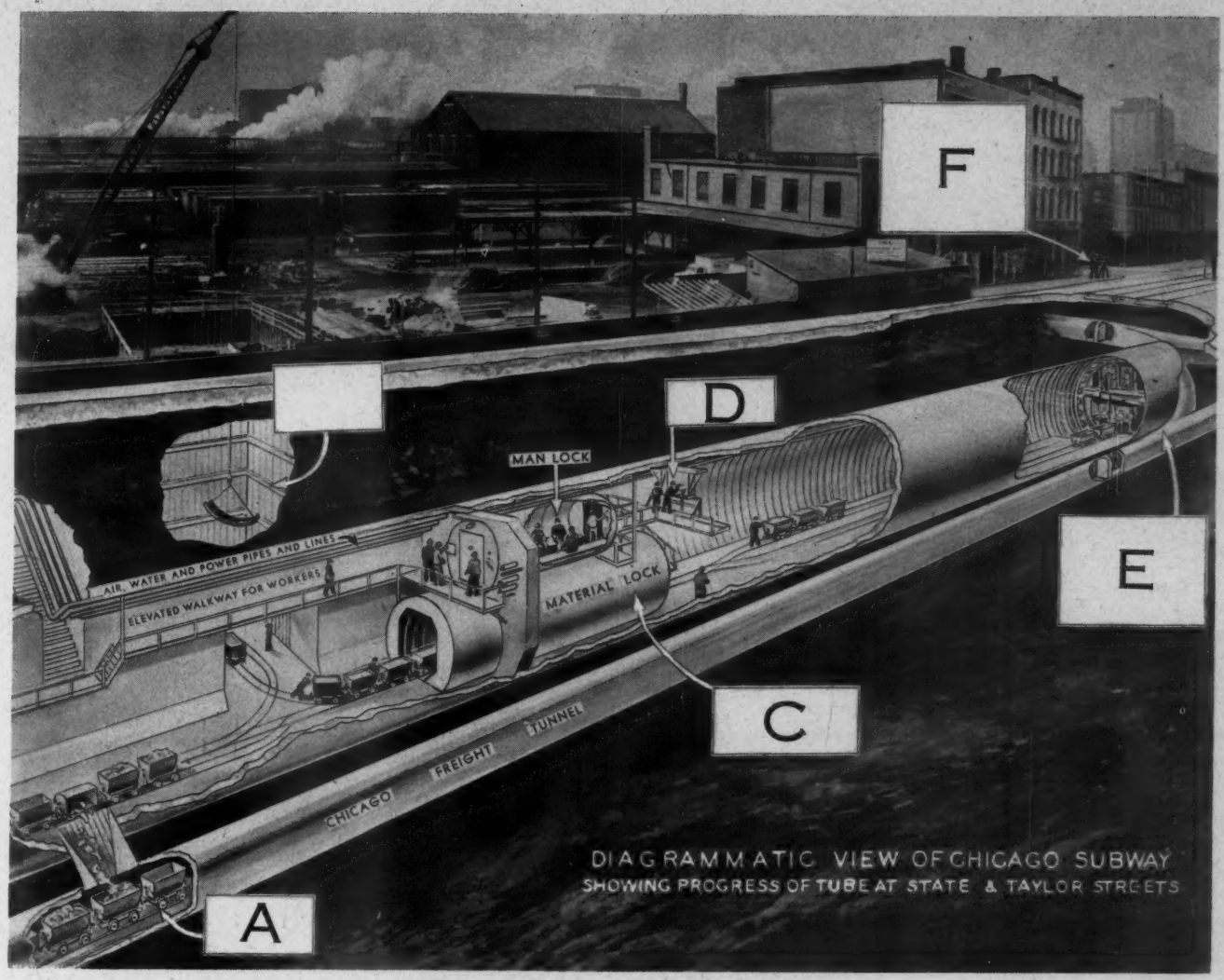
* Chicago City Datum. 579.88 feet above mean tide at New York

In addition, all subway structural steel work had to be designed for basic stresses of 18,000 pounds per square inch tension and 13,500 pounds per square inch shear. In the design of timber structures, wood decking, bracing, and sheeting, which consisted mostly of temporary work, a maximum tensile stress in bending of 1,400 pounds and compressible strength of 350 pounds per square inch across the grain was allowed for.

Another problem which faces the subway contractor and designer is the effect of buildings upon the tunnels. For instance, in the design of the Chicago subway tube within the central business district, determination of tunnel loads required careful study. Besides the wide divergence in age and type and width, height, and depth of the buildings in the proximity of the tube, there also had to be taken into consideration their support. Some of these buildings are supported on footings eight to twelve feet below grade, while others rest on caissons; some have from one to three basements with the lowest floor at approximately subway platform level. Besides the irregularity of loads caused by these

Hand mining on three benches at the face of a horseshoe tunnel section. Miners cut out large chunks of clay with a Chicago clay knife. It is pulled through the soil by a cable attached to an air-tugger.





Diagrammatic sketch of one of the shields in operation

A. Excavated material being dumped into the Chicago freight tunnel; C. Air locks to permit workers to accustom themselves to the tube pressure and through which material is introduced; D. Engineer taking sights to keep digging on a straight line; E. Digging shield; F. Man on surface with engineering instruments checking for any change in the level of the street over the digging. Any movement of the pavement causes him to press a button, ringing a siren below and stopping digging until adjustments have been made.

buildings, consideration had to be given to the possibility of future demolition of some of them and their replacement by higher and heavier structures.

Three general conditions of load predominated in the structures surrounding the subway right-of-way:

Condition 1. This included buildings with one basement and height of not over eight stories. The foundation pressures were light with resultant horizontal and vertical pressures against the side of the tube, compensated by load reduction due to the excavated basement. Here tubes were designed for symmetrical and normal top load of 157,000 pounds per linear foot of tunnel. The ratio of horizontal pressure to vertical load assumed to be from 1/3 to 2/3.

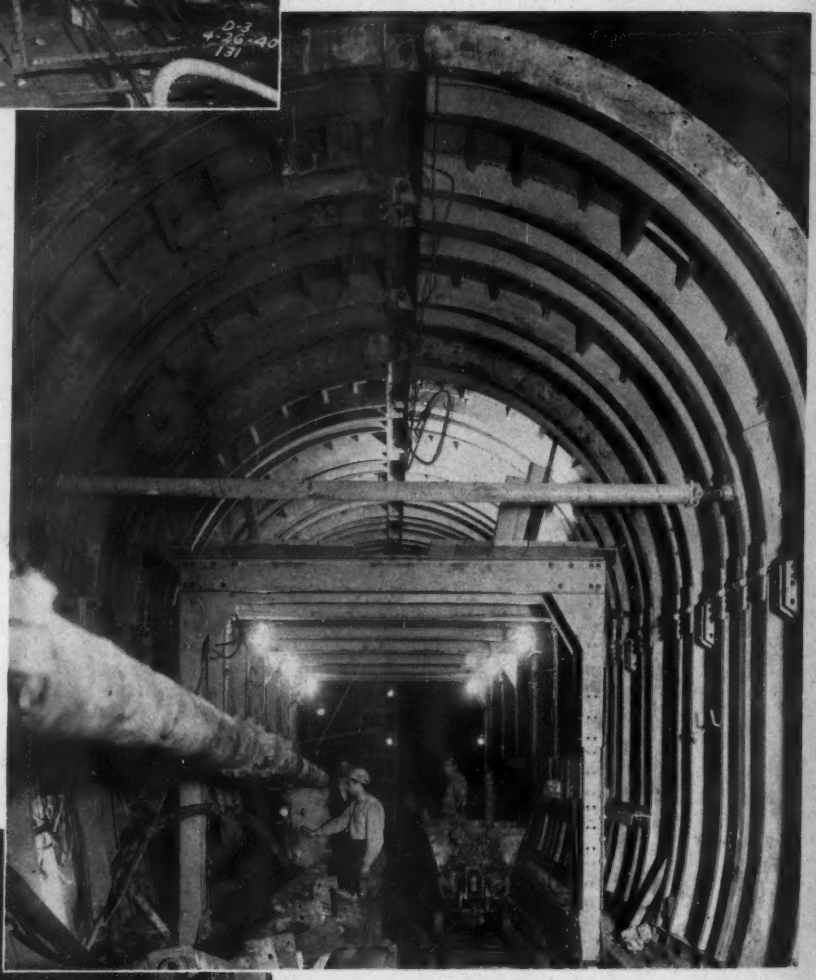
Condition 2. This comprised heavier and taller buildings on spread foundations with one basement. The basement excavation did not compensate for the increase in loading, giving rise to a horizontal pressure-vertical load ratio of from 1/2 to 1/1.

Condition 3. This included buildings on caissons with one or two sub-basements or more. The loss of lateral pressure was not compensated by foundation loads and horizontal pressure-vertical load ratio ranged from 1/4 to 1/2.

(*Continued on page 198*)

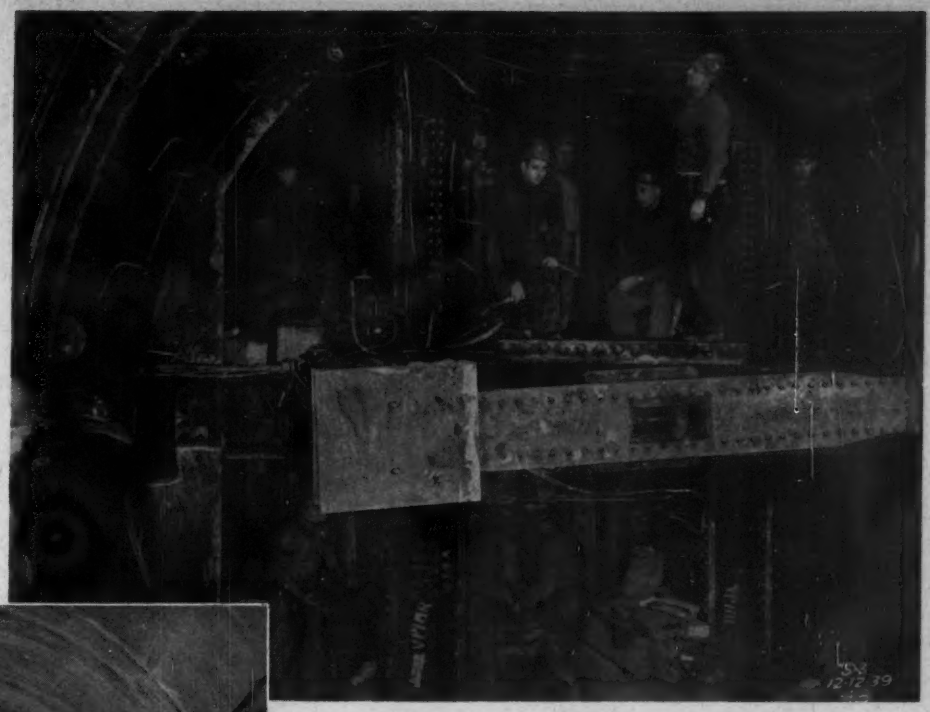
Typical man and material airlock

Installing units of the subway drainage system

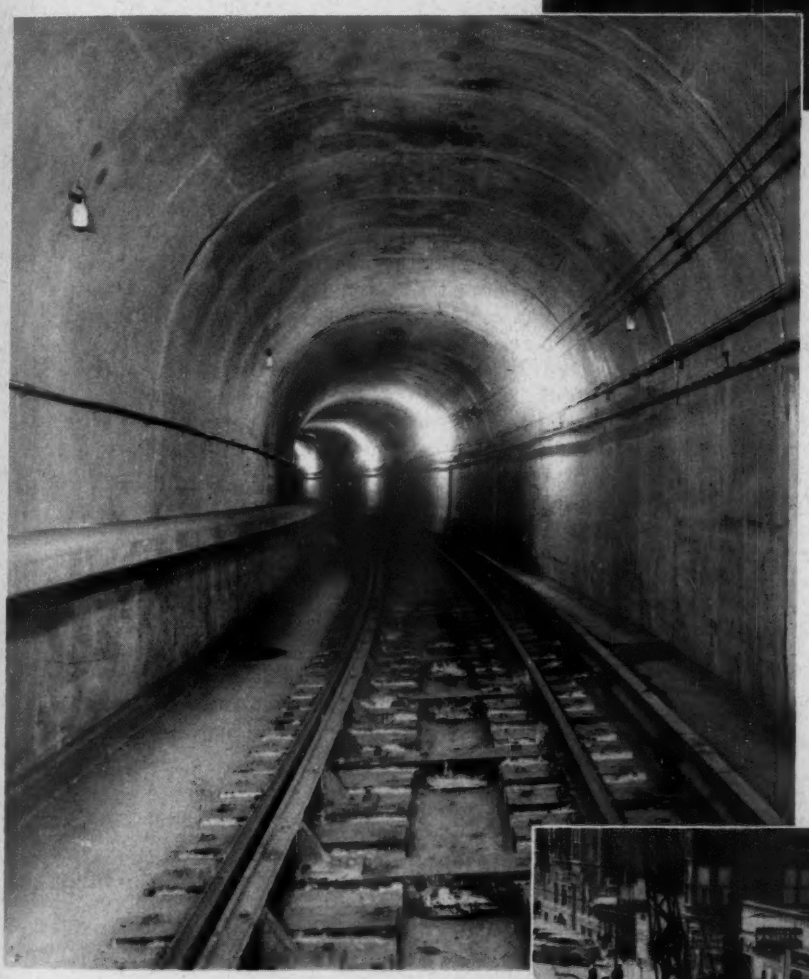


Concrete forms in a place in a horseshoe, hand-mined tube section. When the concrete hardens, the forms are collapsed onto the form carrier and moved forward on rails for the next four.

Placing the running rail. Half ties are imbedded in concrete. Rails rest on tie-plates with resilient pad insets.



Rear view of one of the two shields as it was boring under State Street in Chicago's loop district



Section of completed hand-mined tube with track in place

Mezzanine station under construction. Note heavy decking for street car traffic

THE ELECTRON TURNS CHEMIST

By JOHN S. HOWKINS, JR., 6-45

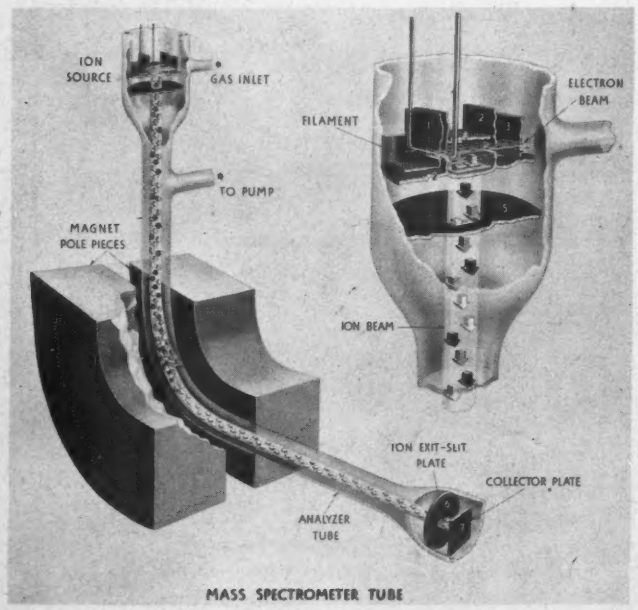
Managing Editor, Tech Engineering News

ELECTRONICS has again added something, and something important, to the scientific and industrial world. This new development, the mass spectrometer, utilizes the dissociation and ionization of gas molecules by electron bombardment to analyze gases. Formerly the analysis of a gas took a skilled chemist several days, but, using the mass spectrometer, gases, even those that cannot be analyzed in any other way, can now be analyzed in fifteen minutes. The average college student, trained in its operation only a few weeks, can run it.

The mass spectrometer should not be confused with the mass spectrograph, of which it is a development. The mass spectrograph is a device for determining the masses of gas molecules and of analyzing gases qualitatively by the action of their ions on a photographic plate, whereas the mass spectrometer, using the same principles, analyzes quantitatively as well as qualitatively.

The main principles governing the operation of the mass spectrometer are two. The first is that unlike charges attract each other, and the second is that a charge moving perpendicular to a magnetic field is deviated from its path into the arc of a circle. The gas to be analyzed is introduced into an electron beam where it is dissociated and ionized. The ions are accelerated in the form of a narrow beam into a uniform magnetic field, where the beam is deflected and where ons of different masses and charges are segregated into separate beams. These beams, on emerging from the field, impinge on a grounded slitted plate. The ions entering the slit are collected in a Faraday cage and the charges they carry are measured by the current travelling between the cage and ground. The radius of curvature in the magnetic field is therefore a measure of the mass of the ion, and the current obtained is a measure of the quantity of that ion in the original gas.

Figure 1. Phantom view revealing basic operation of mass spectrometer



The energy relationship of the accelerated ion is:

$$qV = \frac{1}{2}mv^2 \qquad (1)$$

where q is the charge on the ion in coulombs, V is the ion accelerating potential; m is the mass of the ion in grams, and v is the velocity of the ion in centimeters per second. The force relationship in the magnetic field is:

$$Bqv = \frac{mv^2}{R} \qquad (2)$$

where B is the magnetic field intensity in gauss, and R is the radius of curvature of the ion. From these two equations the radius of curvature of the path of an ion is found to be:

$$R = \frac{1}{B}\sqrt{\frac{mV}{kq}} \qquad (3)$$

where k is a constant of the spectrometer.

From Equation (1) it can be seen that the mass of an ion is a function of the first power of the charge on that ion, but of the second power of its velocity. It is this relation that enables the magnetic field to differentiate between ions of the same masses and different charges, and vice versa. In most cases $q=1$ electronic charge, R is known (it is a constant of the spectrometer, usually between ten and fifteen centimeters), and B and V are known. Therefore the mass of the ion emerging from the exit slit can be calculated.

The current carried by the beam is usually between 10^{-10} and 10^{-15} amperes and requires amplification before measurement. A recording galvanometer is the most common type of current meter used, and it plots the

current carried by the beam focused on the exit slit as a function of the mass of that ion. An example of one of these plots, called the mass spectrum or "autograph," is shown in Figure 4 and is characteristic of the gas.

The key part of the mass spectrometer is a glass tube, the analyzer tube, bent in the arc of a circle. The angle of the bend, usually between sixty and ninety degrees, is limited only by practicality. At one end of the tube is an ionizing and ion accelerating unit, at the bend is a uniform magnetic field perpendicular to the plane of the bend, and at the other end is an ion collecting unit (Figure 1). The inside of the tube is evacuated and shielded with a grounded shield.

The vacuum pump is a combination of a mechanical and a mercury-vapor pump, the mechanical pump being applied first until as low a pressure as possible is achieved, at which time the mercury-vapor pump is turned on. A liquid air cooled condenser is placed between the pump and the analyzer tube to prevent any vapor from entering the tube.

The ion source (Figure 2) consists of an electron gun and ion accelerating plates. Electrons are emitted by the low potential filament, accelerated through slitted plates numbers one and two, at respectively higher potentials, and are collected by the collector plate (number three). There is a uniform electrostatic field, and therefore a uniform electron velocity, between the legs of plate number two, where the gas to be analyzed is introduced.

A uniform gas intake is essential to a uniform ion stream through the tube, and this can be achieved by placing a capillary leak in the intake tube. The rate of intake is approximately 10^{-3} c.c. per minute measured at atmospheric pressure, and, since an analysis uses only about 15×10^{-3} c.c., a uniform intake is afforded if a gas reservoir is used that is large enough so that the decrease in pressure during an analysis is negligibly small.

The molecules of gas, as they reach the electron beam, are bombarded, dissociated or ionized, or both, and are accelerated through the slits in plates two and five, each at a respectively lower potential and both lower than plate four. Plate five is grounded, as is the shielding in the tube. When, therefore, an ion emerges from the slit in plate five, it continues at uniform velocity into the magnetic field.

Entering the magnetic field is a single beam containing all ions accelerated from the source. As the beam enters, all ions are bent in arcs of circles, but some at greater radii than others (Equation 2), those of the same masses and charges continuing as separate beams. One of these beams is focused around the bend and through the exit slit by varying the ion accelerating potential or the current through the magnet. The former method is employed because of hysteresis in the magnet. The ions in the other beams are grounded either on the shielding in the tube or on the grounded exit slit plate, neutralized, and drawn out of the analyzer tube by the pump. Those ions passing through the exit slit strike the collector plate and form a current through the galvanometer. In practise, an analysis is started with a low ion accelerating potential which is gradually increased until the last current peak has been passed.

Since the collector plate is being bombarded by positive charges, it is expected that it will emit elec trons. If this happens the recorded current will be greater than the ion current by the electron current leaving the plate. This secondary emission occurs only when the ion velocity is high, and it can be avoided by placing a negatively charged slitted plate, the retarding

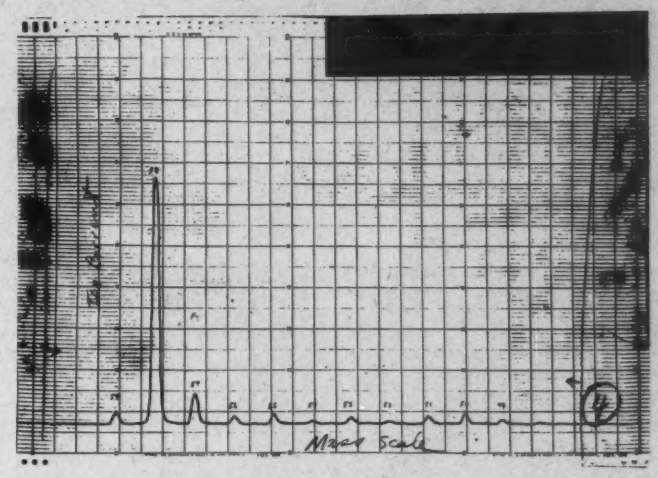


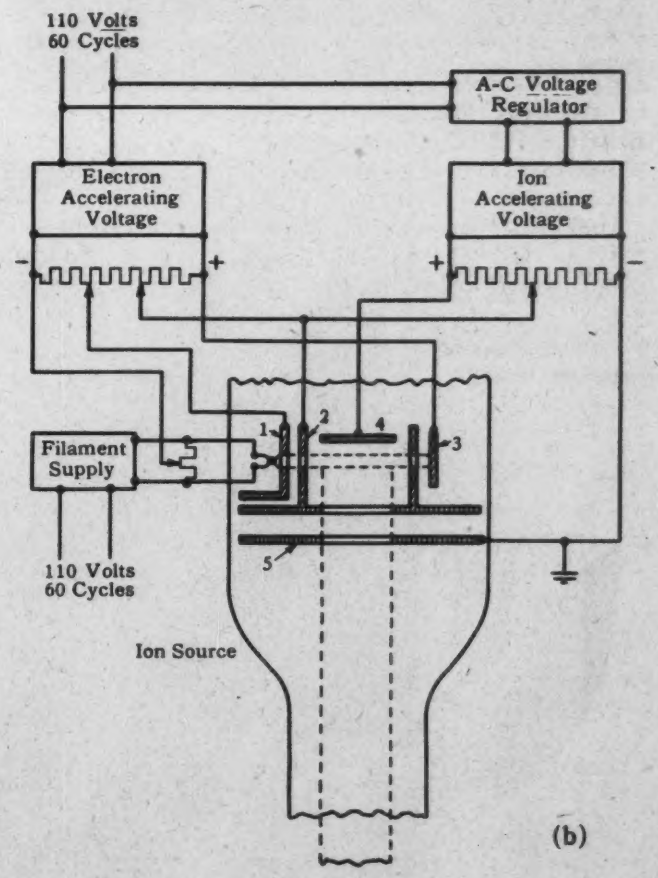
Figure 4. Portion of the spectrum of normal butane (C_4H_{10}) showing the C_4 region of the spectrum

slit plate, between the exit slit plate and the collector plate. This repels the emitted electrons and sends them back to the collector plate.

Needless to say, the operation of the mass spectrometer is not cut and dried. The preceding discussion was based on the analysis of positive, singly-charged ions. Some gases, but not many, ionize negatively. If this is found to be the case, the ion accelerating potentials are reversed, as is the magnetic field. The procedure is the same as before. Whether or not an ion has a single or double electronic charge is found by experience.

(*Continued on page 206*)

Figure 2. Close-up diagrammatic view of the connections at the ionizing source of the mass spectrometer



PULP TO

CUTTING THE TREES

Two "flat heads" (log cutters) preparing to harvest a mature pine tree

PULPWOOD STACKED FOR THE MILLS

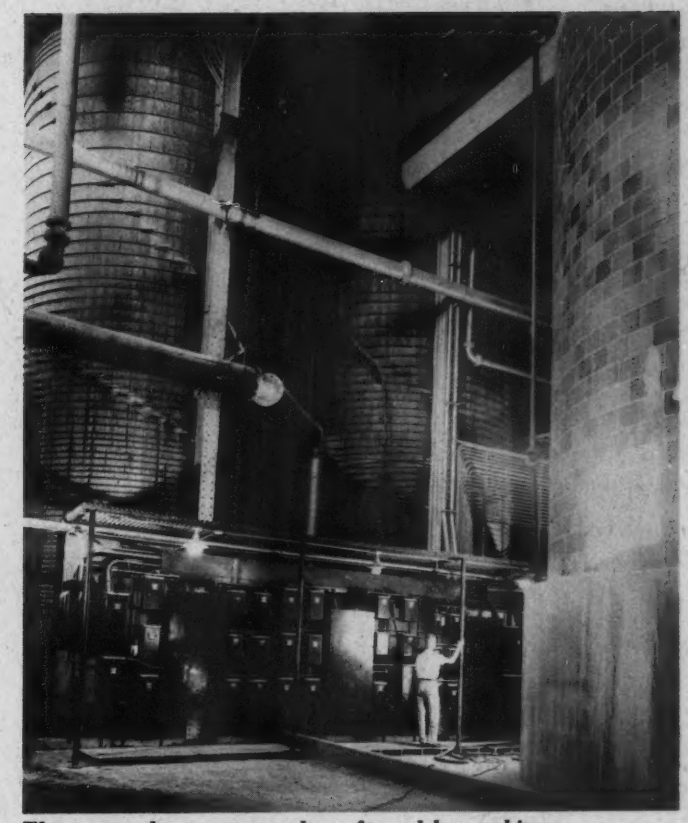
CHECKING THE CHIPS

Chips are graded and conveyed to mill

Pictures courtesy The M
and American Forest Produc

D PAPER . . .

A STRANGE STEW



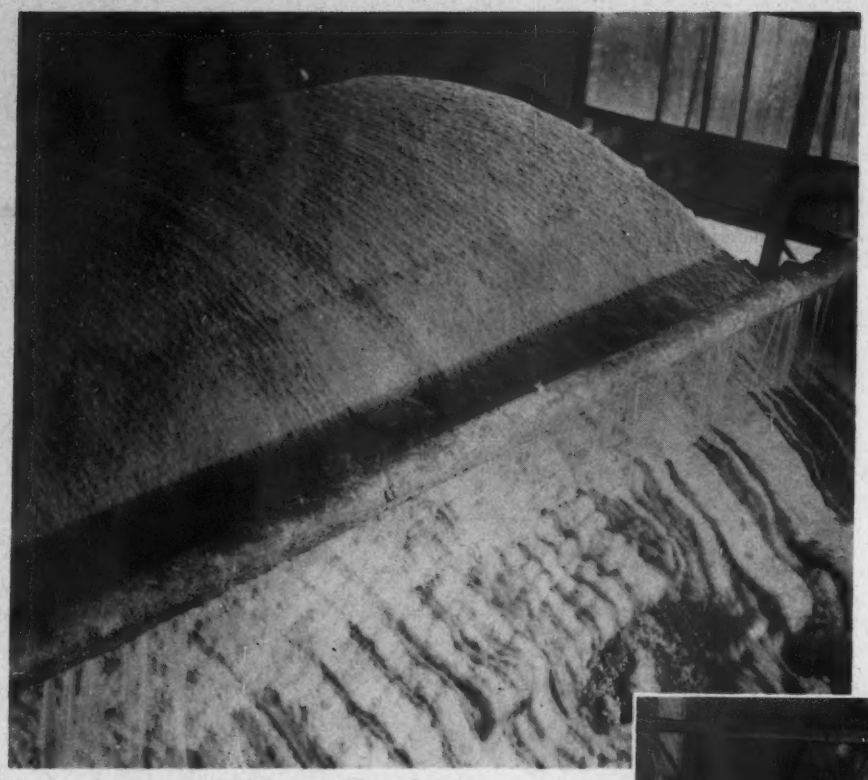
The raw pulp must next be softened by cooking

BLEACHING THE PULP

Pulp is cleaned and bleached

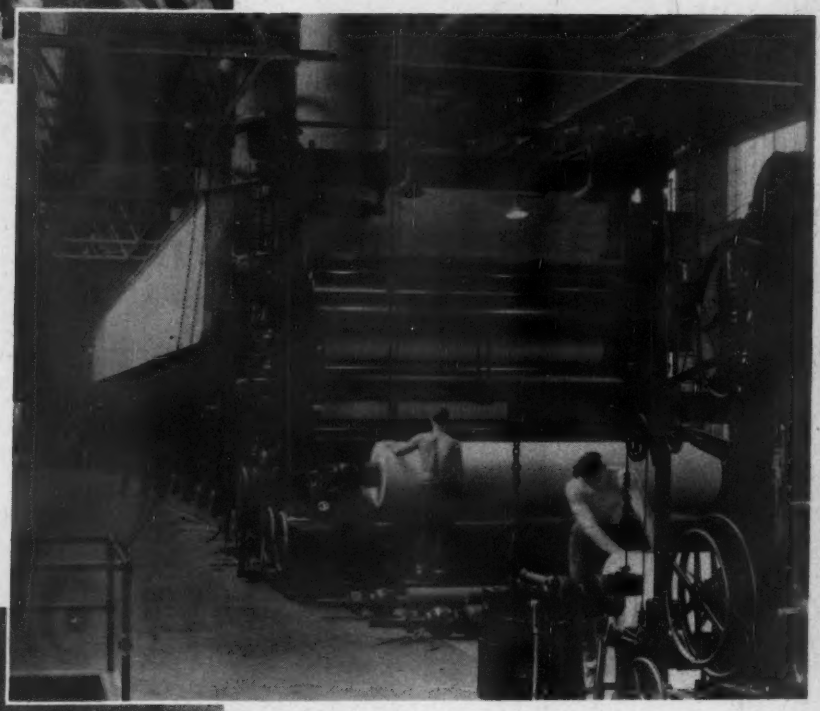
ourtesy *The Mead Corporation*
Forest *Products Industries, Inc.*

SCRUBBING IT DOWN



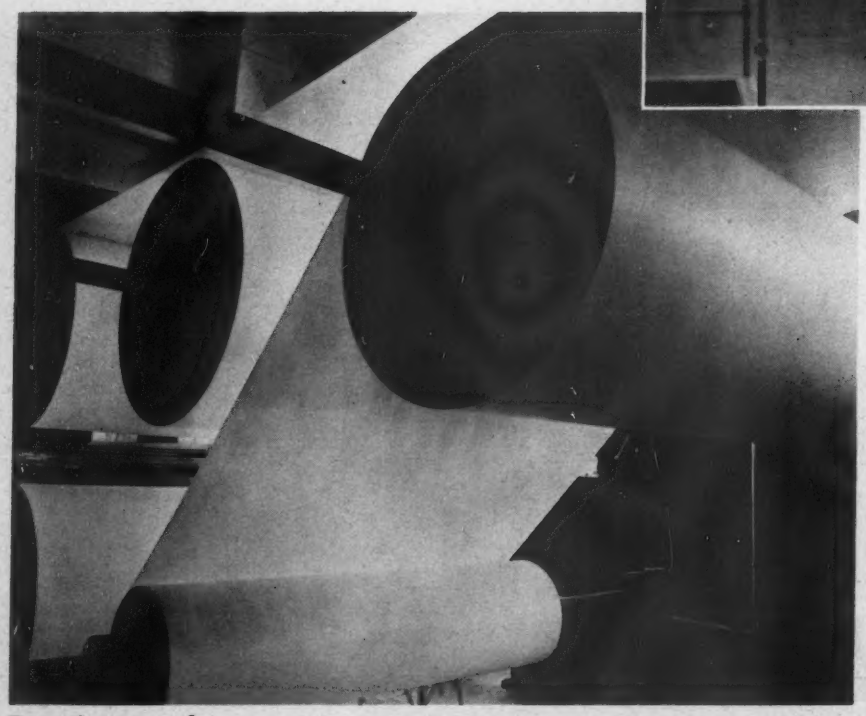
Here pulp is washed with pure filtered water

IT MUST BE DRIED . . .



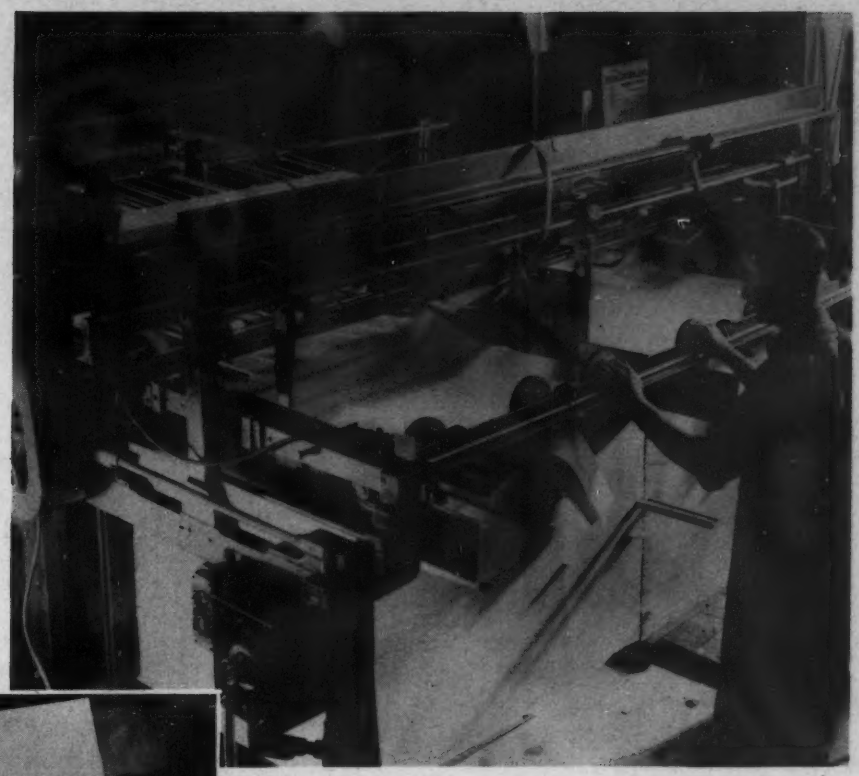
Paper is dried by heated rolls

. . . THEN REWOUND



Paper is rewound

CUTTING THE PAPER TO SIZE



THE PAPER IS REWOUND . . .

Rewinding the paper after slitting

. . . AND GIVEN A FINAL INSPECTION

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DEAR MR. EDITOR:

In the February issue of THE TECH ENGINEERING NEWS you included an editorial which I believe is of particular interest to all thinking people, not just to the engineers to whom it was addressed.

The writer of that editorial subscribed to the proposition that the widespread destruction being wrought over half the world is preparing the way for an engineers' field day, in which it will be his job to rebuild the war-levelled continents. The writer implies, yes, even expresses, considerable joy over this destruction.

This is dangerous thinking! Let us hope that the opinion expressed in this editorial is not indicative of a trend in the thinking of American youth. The many people with whom I have spoken about this editorial agree with me in more or less degree that it smacks of Nazi thinking. Do you not agree with me, Mr. Editor, that it is the very antithesis of the so-called "American way" to advocate or even approve destruction for the sake of destruction?

The action and words of the governments and military leaders of the United Nations testify to the fact that we are destroying only after careful consideration of whether or not that destruction is *absolutely essential* to victory. Only lately has there come additional testimony. President Roosevelt announced at his press conference, simultaneously with announcements from the military leaders in the area, that after careful deliberation it had been deemed necessary to bomb and shell the ancient Benedictine Monastery at Cassino, because the Germans had chosen to employ it as a fire control point. Its existence as a German outpost was resulting in the sacrifice of American lives. Certainly this was justification in itself for the action taken. Yet that action came only after thorough investigation of the situation to insure that there was no possible way to avoid it by changing the plan of action, or by bringing about voluntary German withdrawal.

With all this, it must certainly be a source of regret to every thinking person that this action had finally become necessary. Yet the writer of your editorial, Mr. Editor, would seem to try to add to this sufficient justification by saying, "Here is another challenge to American engineering ingenuity. It will be interesting indeed to watch and see whether or not we shall be able to restore this sacred monument to its original condition."

And what, Mr. Editor, of the cost of rebuilding three continents? It will be interesting, too, I suppose, to watch future generations faced with the necessity of burdening themselves with debt that we may restore the war-torn world.

For the sake of saner, clearer thinking in the postwar world, let us realize at once, Mr. Editor, that the destruction which is taking place is nothing to rejoice about; rather that it is an unfortunate necessity. And please, let us not forget that word "unfortunate." At all odds, when you state that as a result of the war a condition will obtain which "will truly be a Tech man's paradise," you are demonstrating a faulty brand of thinking.

I agree with you that a monumental task faces the postwar engineer, but let us face that task soberly, determined to build a better world in the smoking ruins. Let us not look happily upon the misfortunes of others, considering them as a source of capital and field of experiment for ourselves. If we have reached the point where we must rely on wars to provide employment for engineers, then perhaps we had better close the technical schools and put all the engineers on the WPA, building more and better toothpicks.

In conclusion, I should like to point out what I believe is another shortcoming of the February editorial. (Or was it simply an oversight? I hope that this latter was the case.) "America and Great Britain will be the victorious countries." One of the cardinal points upon which a lasting peace must be predicated is the principle that it will be a victory of the United Nations, *united* now, *united* at the peace table, and *united* for permanent peace through permanent coöperative effort. I do not believe that this coöperation is being fostered by careless statements which claim for America and Great Britain all credit for the coming victory. The contribution they are making is great indeed, but can anyone say honestly that it is any greater than the contribution being made by the people of the occupied countries and our fighting allies? Each is contributing to the fullest of their ability. One can ask no more. It is the right of each to expect no less. Let us not belittle the efforts of others, but rather make a greater effort ourselves. Only in so doing can we insure victory.

Very truly yours, CARROLL BOYCE.

An appropriate answer is in the process of being written and will appear in the April T. E. N.

Tough problems in Engineering . . . licked in record time

New Radio—with 80 voices—revolutionized our tank warfare

IN 1940 the Signal Corps brought one of its toughest radio assignments to Bell Telephone Laboratories and Western Electric.

A rugged multi-frequency set was wanted for the armored forces. It must be, in effect, a radio switchboard to interconnect tanks, scout cars, command cars, artillery units, anti-tank vehicles.

The model was ready in one quarter of the time normally required to design and build such a complex set—an FM transmitter and receiver having 80 crystal controlled frequencies. Any 10 crystals could be quickly plugged in—and push buttons provided instant switching from one channel to another. The set was tested—accepted—ordered in quantity.

Meanwhile Western Electric engineers were tackling knotty production problems—tooling up of plant, training girls for the exacting work, procuring raw materials, setting up complex testing procedures.

Among the toughest problems were those of crystal manufacture. Millions of these tiny quartz wafers would be needed—each lapped to dimensions, silver plated in a vacuum, and mounted on wires so small that they must be soldered in place under a microscope. Amazing new machines and methods were devised—and the crystals came out on time.

Radio, electrical, mechanical and industrial engineers at Western Electric—Bell Laboratories men and Signal Corps men—all contributed invaluable aid. Early production goals were met—volume increased steadily.

Today huge numbers of units have been delivered. They are providing the instant communications that enable our armored forces to travel farther and faster and to hit harder!

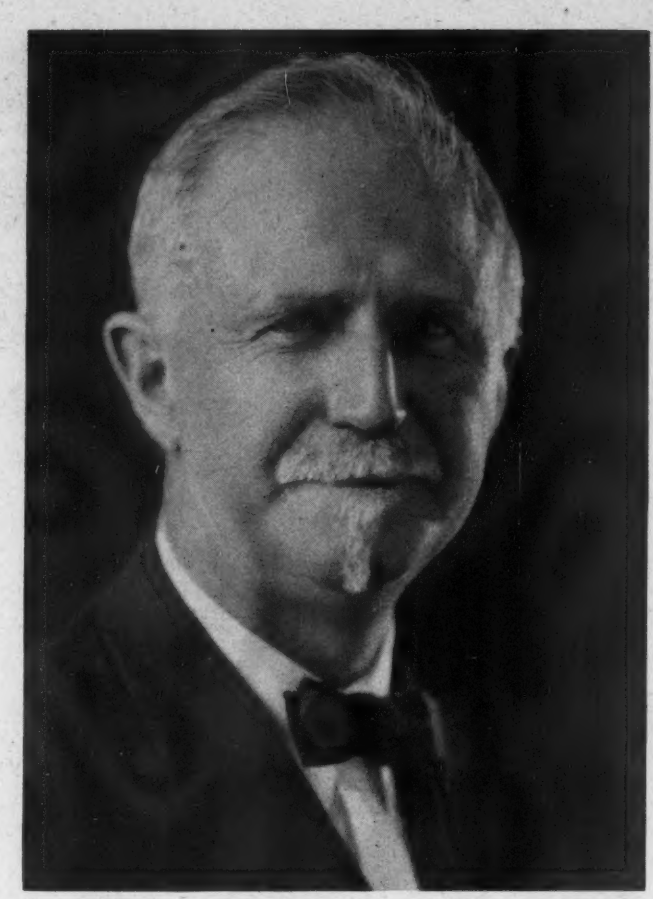
Buy War Bonds regularly — all you can!

75TH ANNIVERSARY
Western Electric
IN PEACE . . . SOURCE OF SUPPLY FOR THE BELL SYSTEM.
IN WAR . . . ARSENAL OF COMMUNICATIONS EQUIPMENT.

ALUMNUS OF THE MONTH

ROGER W. BABSON, '98

Businessman, Educator . . .



Roger Ward Babson, one of the most outstanding and inspiring personalities in American business today, entered the Massachusetts Institute of Technology with the Class of 1898. Although he had no preferences with respect to a course of study, and attended the Institute only at his father's request, he pursued the course in Civil Engineering. However, he became more and more determined to enter the business world. Had there been a Course XV in existence at his time, he would undoubtedly have entered it. In fact, he expressed his hearty approval when, some years later, such a course was formed.

Babson, reared in an old-fashioned atmosphere of hard work, hustle, and economy on a farm in Gloucester, had the good fortune of possessing a father who guided him fairly but firmly and a mother who aided him tremendously by her studied attitudes toward him. Perhaps this is his reason for continued insistence upon the value of good ancestors. Soon after his graduation from the Institute he entered business. After going through the usual ups and downs of a young businessman Babson began to work on Wall Street. Here he found matters not to his liking, so he left, deciding to set up business elsewhere. In 1900, shortly after his graduation from the Institute, he married a girl who was to be a very capable partner, Grace Knight. Both were hard workers and made a competent and energetic team.

Two years later the pent-up lightning of overwork struck. Babson came down with tuberculosis. At first the doctors told him that it was just a cold which had "settled on his lungs." Babson, determined to cure his ailment, kept asking what was really wrong. Finally he was told of his condition. In characteristic Babson style, he said: "All right! Now that I know what's the matter with me, I can go to work to cure it!" So he "went to work" and cured himself by living in the open air, winter and summer, The results were amazing!

Even while he was overcoming his illness, a considerable lapse of time, he did not and could not remain mentally idle. It was while he was going over the usual monthly reports of various companies that he decided that there was an expensive duplication of effort in the plan whereby each company analyzed and tabulated such data independently. Thereupon he organized a firm that could do this work and sell its services to the companies. With only $1,200 capital at the start, this was the humble yet stupendous beginning of the now nationally known Babson organization.

The organization grew much more rapidly than Babson had ever dreamed. First one building and then another one were commandeered to house it. Each gave way to a larger one, until today the organization is housed in a number of large buildings which far exceed in size the original layout.

Another, and perhaps the most important brainchild of Babson's is the Babsonchart. This chart, a complex system of lines charting past and present business, indicates trends of business and serves as a remarkably accurate barometer of business trends. It is a boon to businessmen in that they have the past, present, and future of an enterprise at a glance, making unnecessary an extensive individual research into the subject. Like this chart, many of Babson's predictions have also proven remarkably accurate. He has repeatedly prophesied business rises and drops and amazed everyone with his uncanny foresight. It is perhaps interesting to note that he predicts the defeat of Germany this year. He also says that there will probably be more labor disputes and wage increases this year.

After having achieved what others would call the height of success, Babson went on with his intentions and enterprises and founded the Babson Institute, a business school for men which, in his own words, was to "concentrate more upon the fundamentals and less upon the frills of business." Later, in coöperation with his wife, Webber College, a similar school for women, was founded in Florida. Both have been remarkably successful. Babson is responsible for various firsts in Wellesley, Mass. and vicinity, such as the first motion picture theatre, the first radio station, and the first airplane field. A prohibitionist at heart, his "only regret" with regard to radio stations is that they have permitted advertisement of liquor, tobacco, and worthless patent medicines. Mr. Babson has written many books on business investments and similar subjects and about an equal number on religion in today's world. He is vitally interested in religious education and believes that it is indispensable in today's chaotic and war-torn world as well as in times of peace. Likewise a great believer in the factors of heredity, he has written much advice about these and many other subjects in his numerous works, addressing it to both young and old people. It is remarkable to see how much a powerful business man can do for others and how much he can make others do for themselves. Since, however, this has been Babson's purpose throughout his life, it is and has been expected of him, making the whole situation even more to be admired.

Do You Know These

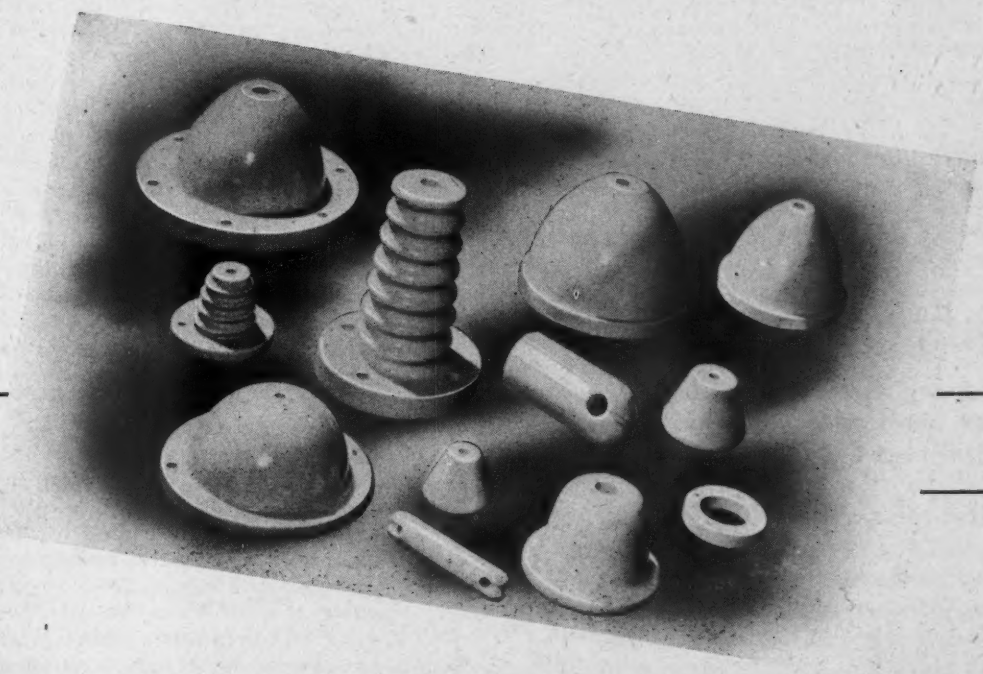
FACTS

ABOUT STEATITE

Steatite, or massive talc, is a magnesium silicate. When used as a raw material, it imparts unusual insulating properties to ceramic products. The name Steatite is generally used to describe ceramics which contain a preponderance of talc.

Massive talc is mined, sorted, cleaned and ground, and is used by the cosmetic industry as well as in ceramic manufacture. Talc of the highest purity is demanded for insulators, only ten per cent of the mined talc being suitable for the Steatite and High Dielectric Insulators of the General Ceramics and Steatite Corporation.

These insulators are used by leading radio and electrical manufacturers, not only in equipment for commercial use, but also for equipment built to the specifications of various governmental departments.



ARMY E NAVY

General Ceramics

GENERAL CERAMICS AND STEATITE CORPORATION STEATITE INSULATORS

AND STEATITE CORP.

KEASBEY NEW JERSEY

BUILDING A MODERN SUBWAY

(*Continued from page 185*)

These three conditions alternated planlessly throughout the structure.

Pressures against the tubes were determined from Boussinesq's equations which are strictly limited to the stresses in a semi-infinite solid under a surface load. Because neither the weight of a building nor the negative load caused by the excavation of its basement could be considered as applied at the ground surface, it was necessary to make approximations in computations. Final values which were believed to be nearly correct were tabulated and plotted in such a manner that the resulting graphs showed the vertical and horizontal components of pressure against the tube as well as the variation in both a vertical and horizontal direction.

At the location of mezzanine stations loading conditions were greatly complicated. Within a short distance, the typical arch section changed to one where the center arch was replaced by an irregular girder stressed in two directions. Next it changed to an open well section where the center arch was removed to accommodate escalators and stairways, and finally to one where the center arch was replaced by the escalator machinery room floor slab.

Previous to the construction of the mezzanine stations, all of these sections carried basic normal loads. After the mezzanine was built, the greater part of the station weight and that of the overlying soil is carried directly into the walls and columns of the subway tubes and partly into sub-piers. Consequently, the top arches carry only about one-third of the total normal load while the horizontal pressures remain as before, causing heavy positive moments in sides of tubes and tending to bend the top arches upward.

For many months efforts were centered on the problem of devising a method of ring stress analysis that could be applied to tunnel rings of any size and shape and yet yield fairly correct values. A search through engineering literature proved fruitless. In the end, the classical "Energy Method" was adapted for the purpose, and a series of stress computations were carried through for fixed load but different conditions of redundancy.

The resulting values were used to establish rational standards of loadings, determine suitable statically determinate base systems applicable to all tunnel sections, and deduce conclusions and working rules, all intended to reduce the labor of computation and simplify design. Some of these standards are listed below:

1. The effects of arch thrust and shear upon deformation of structure were small and could be ignored.
2. Steel columns were relatively flexible and for symmetrical loading took vertical loads only. In design, however, moments resulting from rotations and displacements at column top and bottom had to be considered.
3. Column girders were rigid vertically and were fixed horizontally by adjoining arches.
4. Torsional formations in the side arches were negligible in arch analysis but had to be considered in design.
5. In analysis only one-half of the structure had to be considered as it was always possible to replace unbalanced loadings by a combination of equivalent symmetrical and polar-symmetrical loads.

Thermal and shrinkage stresses were also given consideration. At the time of construction, the air pressure within the tubes ranged from eight to fifteen pounds with attendant high humidity and average temperature of 90° F. The temperature of concrete at the time of pouring was about 70°F., rising to about 100°F. after the concrete was placed and while set was developing. The temperature was still high when the set had been completed and bond had developed between concrete and steel. The initial heat in concrete, plus that generated by the chemical reaction of cement and water, radiates rapidly, and this caused concrete and steel to contract and develop stress in proportion to their respective coefficients of contraction. Later, when excess air pressure was removed, tunnel temperature decreased and reached limits of 30° and 70°. Still later, when the tubes were ventilated by operation of trains and by the supplementary forced draft ventilating system, it was assumed that temperature in the tubes would fluctuate with ground surface temperature to a probable low of ±25° F. and a high of ±85° F. With a temperature at the outer face of the shell remaining constant at −55° F., it was apparent that the difference of −25° F. would cause moments and stresses that had to be added to those due to external loads. Because of the many uncertainties inherent in thermal and shrinkage problems, no attempt was made to calculate stresses by a precise theory. The analysis was based on the assumption that for any arch element of length (ds) the angular change due to $t°$ temperature difference could be equated to $\frac{M_t(ds)}{EI}$.

After the difficulties of planning were solved, the next step was the excavation of the tunnel.

Because of the varying soil and surface load condi-

(*Continued on page 200*)

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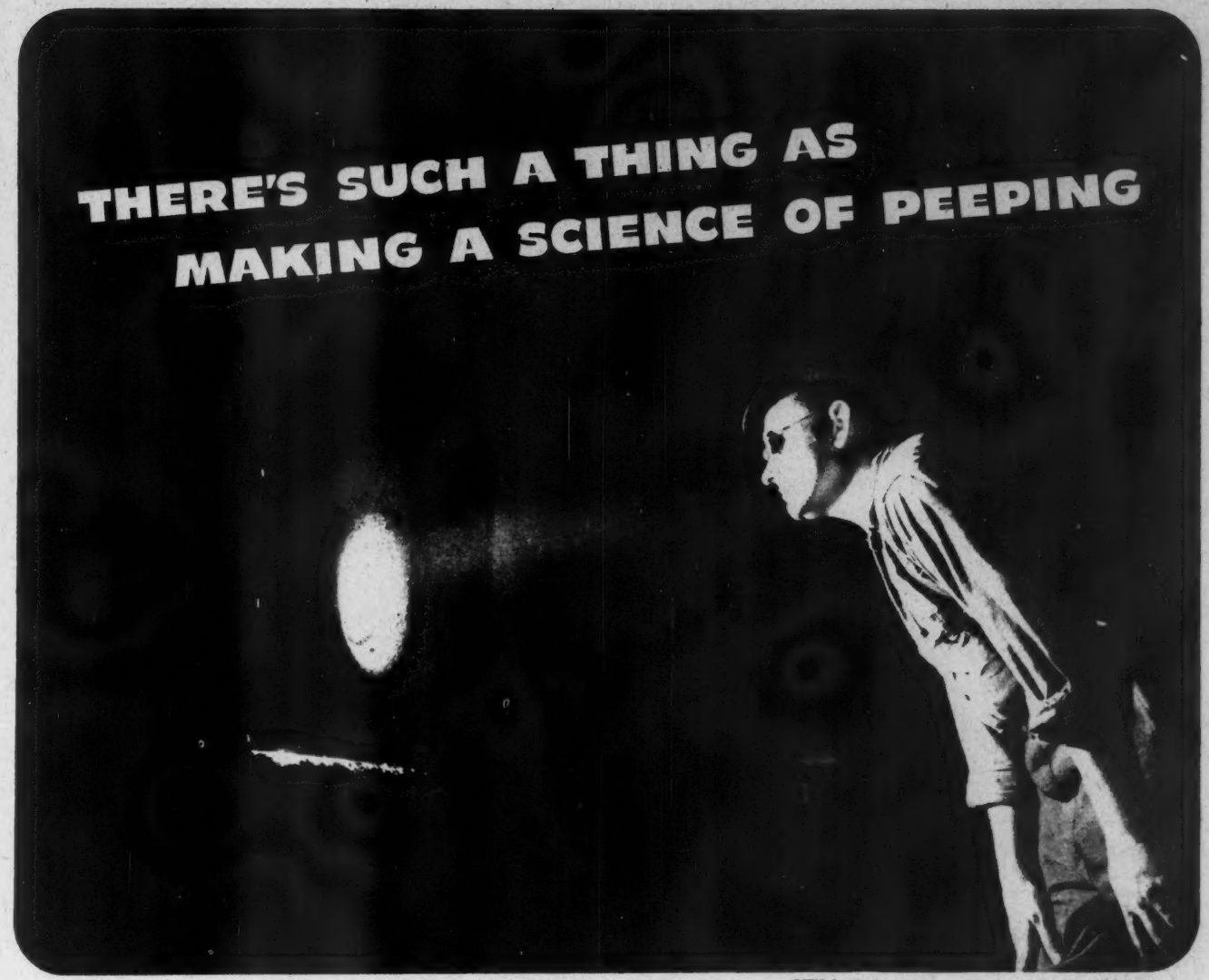
THERE'S SUCH A THING AS MAKING A SCIENCE OF PEEPING



OWI by Palmer, in an Allegheny Ludlum Plant.

WITH this melter, studying the action of some 35 tons of alloy steel in an Allegheny Ludlum electric furnace, peeping is resolved into a science.

His job is one of the earliest in a long series of operations which bring a melt of Allegheny Ludlum stainless, electrical or other alloy steel to its final form, rigidly true to specifications. His experience determines whether the molten mass within the furnace is progressing at the proper rate, and dictates any adjustments necessary to produce the quality of steel specified. His judgment is double checked, of course, by thousands of dollars worth of amazingly accurate testing equipment, built for analyzing with hairline precision.

For, in wartime especially, the properties of alloy steels must be maintained with the utmost consistency. Lives of men—even the outcome of battles depends upon this uniformity, because the place of alloy steels is always in the vital heart of a war mechanism.

Lives and battles depend upon other things in this war, too—matters that come home to every household. Buying bonds, conserving food, fuel, gasoline, rubber, waste fats and scrap metal—all these have to do with how soon the war will be won, and at what price. They are *everyone's* jobs. Have you done —are you doing—*all* you can?

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BUILDING A MODERN SUBWAY

(*Continued from page 198*)

tions along the route, two methods of tunneling were used. The bench type method was employed for all of the subway tubes north of the Chicago River. In this area, the soil was a medium plastic clay with a relative high bearing value. South of the Chicago River, the shield method was used. Here, the soil was very soft and the water content was high. There were many buildings on spread footings. Deep sub-basements and numerous utility vaults complicated the problem of tunneling in this soft clay. In addition, the Chicago freight tunnel, at subway level in this area, had to be removed ahead of excavation for the subway tubes.

The bench method of mining, as its name implies, consisted of advancing the horseshoe-shaped excavation in a sequence of benches. In general, the clay was mined with power knives pulled by cables attached to air motors.

In this procedure, the first step was to advance a small pilot tube, or "monkey drift," on each side of the main tube at the spring line. These drifts were usually carried about 12 feet ahead of the crown mining face. An eight-inch "H" beam section was set on wood blocks in each "monkey" drift with the web horizontal. These beams were usually 12 foot sections, except on curves.

The top or crown face was excavated for a distance equal to the width of a liner plate, usually about 30 inches. Two six-inch steel I beams, bent to form a transverse rib, were set to bear on the web of the wall beams and were joined at the crown and securely bolted. Steel liner plates were set between these ribs and were either bolted to the web of the rib, or placed behind the back flange of the rib.

Before the sides and middle face were excavated, mining at the crown face was advanced about 12 feet with the steel arch lining closely following. Then a vertical cut was made along each side of the tube to the bottom of the section, and steel posts, based on grillages of hardwood blocks, were placed under the wall beams at about 30-inch intervals to support the side of the excavation. Thereafter the middle bench was excavated and the invert block was mined. In this type of mining, the reinforced concrete lining usually followed within 100 feet of the face of the tube.

The second tunneling method, the shield method, was used in the soft earth in and around the Chicago River. Two shields, each about 25 feet in diameter, 20 feet long and approximately 25 tons in weight, were employed. Each shield was moved forward by twenty-four hydraulic jacks having a combined shoving capacity of about 5,000 tons. The pressure actually used, however, was considerably below total capacity. As a shield was moved forward by the pressure of its jacks against the steel lining, clay squeezed through six ports in the face of the shield like toothpaste from a tube and was cut off with wire and tossed into muck cars. The area of the ports varied with the consistency of the clay.

After each forward shove of the shield, a distance of 33 inches, a ring of heavy steel lining, consisting of heavy plates strengthened by structural steel shapes, was erected within the tail piece of the shield. A completed ring was formed by six segments and a key section and was 33 inches wide and 24 feet nine inches in diameter and weighed about five and a half tons. These segments were too heavy to be handled by hand and were lifted and placed by a hydraulic erector arm on the shield.

A complete cycle of shoving the shield and erecting a ring of plates could be completed under ideal conditions in about an hour and 20 minutes. Forward progress, however, averaged slightly more than one foot per hour. When obstructions were encountered in front of the shield, it was necessary to stop shoving and mine in front of the shield to remove the obstruction.

Extreme care had to be exercised in shoving the shield to avoid causing bulges and dips in the street surface. Engineers, who had direct means of communication with the operators of the shields, were stationed on the surface constantly checking for any undue movement in the street or adjacent buildings. When disturbances were noted, the shields were stopped instantly, an investigation made, and the cause of the disturbance was eliminated.

Plant sites of each contract section, bench mined and shield mined sections, were selected off the street to avoid interference with traffic. Each of the five contract sections was worked from a single shaft that generally was connected with the subway tube by a drift tunnel. Hoisting equipment in the shaft handled construction material and in some instances excavated clay as well. Field offices, electric shops, compressor rooms, repair shops and workmen's change rooms were located in the shaft sites.

Due to the great pressures surrounding the tube caused by the earth, the entire excavating section had to be maintained at a pressure eight to fifteen pounds above atmospheric. In order to insure this pressure at all times, duplicate banks of compressors were installed on each section, and two separate sources of electric energy were provided. Air locks had to be placed at all

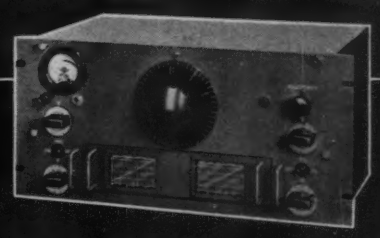
(*Continued on page 202*)

OFFICIAL PHOTOGRAPH
U. S. ARMY AIR FORCE

A LONG WAY FROM HOME!

● **Boring into the sunset, this Mitchell has a rendezvous with danger. Armed to the teeth, and freighted with destruction, she will fight her way in to the "target for tonight" and she will fight her way home again. She and her sisters have a deadly job to do, and radio will help them do it.**

Ground stations around the world depend heavily on the HRO receiver for dependable communications with aircraft.



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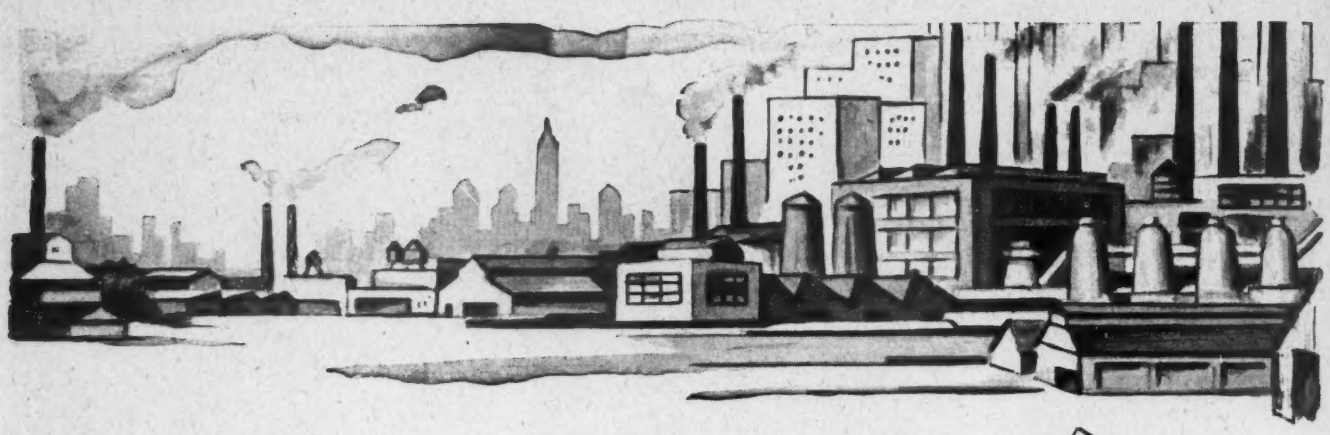

BOILERS OF THE FUTURE

The pressure of war-time production has demanded of Babcock & Wilcox an ever-greater share of the responsibility for producing boilers for increased-capacity steam generating plants. A large number of Public Utilities, Industrial Power Plants and Ships have been equipped with B & W Boilers of modern design. These improved boilers will be available for FUTURE use in ALL industries. It would be well to familiarize yourself with B & W Boilers NOW.

BOOKLET

"The Design of Water-Tube Boiler Units" is a 14-page booklet that explains what type of boilers are used for various types of service. Copy FREE on request.

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BUILDING A MODERN SUBWAY

(*Continued from page 200*)

working points to introduce men and material. Excavated clay was hauled out of the tubes in industrial cars on narrow gauge tracks, pulled by battery locomotives. A large amount of it moved through the freight tunnel system, thus avoiding interference with traffic.

The heavily reinforced concrete lining of the tubes was cast in two sections, the invert portion first, followed by the arch and side wall portion. After reinforcement steel and drainage pipes had been placed, the invert forms were set and the concrete for this portion was poured. When this had hardened sufficiently, and the reinforcement steel for the sidewalls and arch had been erected, steel forms were moved into place on rail carriers, and braced. A pipe carrying concrete was run to an opening in the top of the form and the concrete was pumped or blown into the form. This operation was checked through inspection doors in the forms. Both external and internal vibrators were used to obtain a dense concrete.

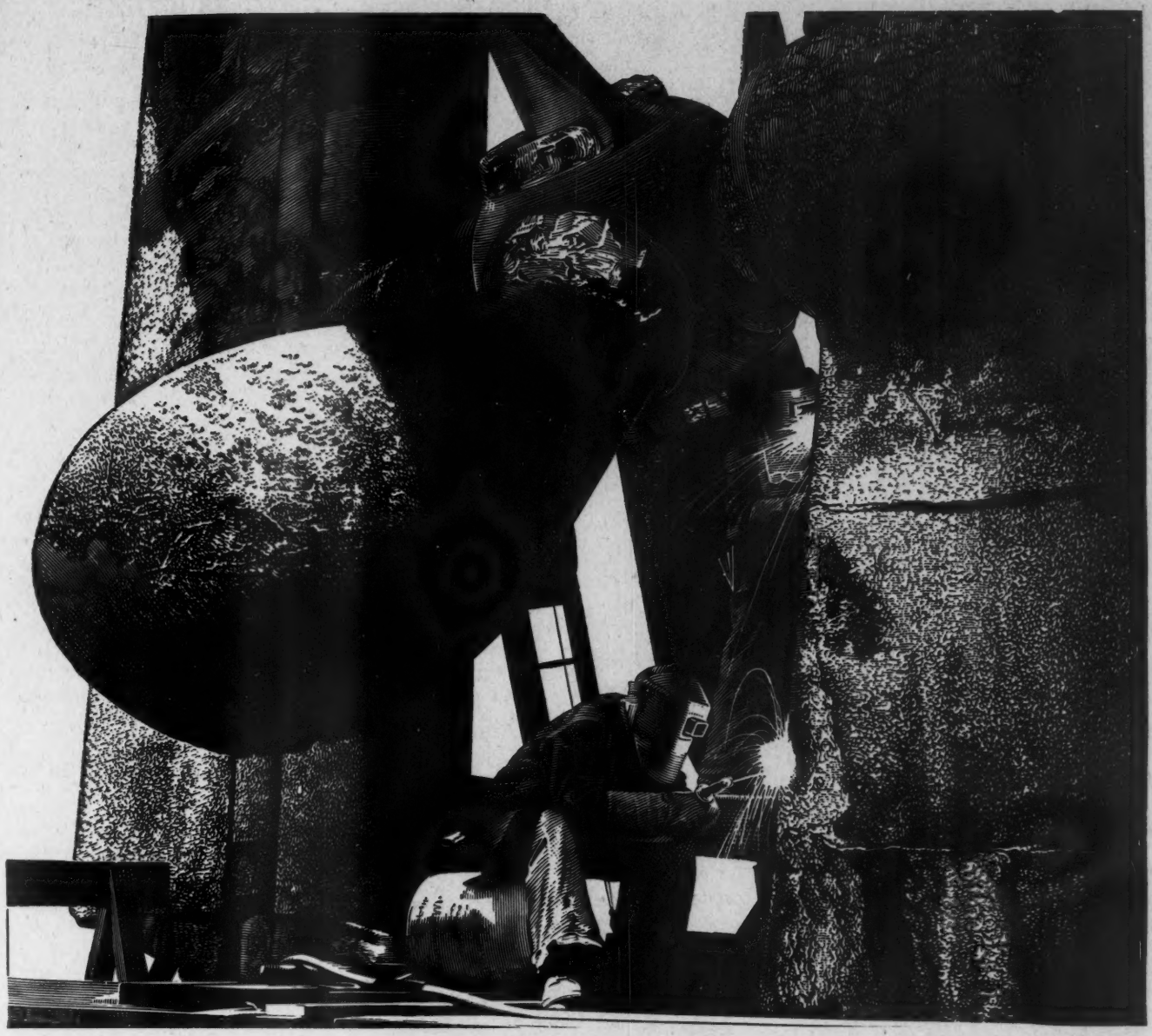
There were also many minor problems to be solved, such as excavating for the loading platforms at the station sections. This was done by mining the area between parallel shield driven tubes, and in the case of side platforms stations, additional sections were mined on each side of the tubes. Auxiliary structures, such as ventilation shafts, pump and electrical rooms, were constructed after the tubes had been completed and the air pressure removed.

Another problem had to be faced in crossing the Chicago River. Because there was insufficient clay cover safely to tunnel under the river, double train tubes, 200 feet long, were prefabricated, and then lowered to concrete mats in a previously prepared trench. Sand back fill was then placed under and around the tubes, which were connected to the main tubes by sections constructed in cofferdams and by tunneling.

One of the more noteworthy aspects of the Chicago subway is its lighting system, since it is the first subway in the nation and probably the first in the world to use fluorescent lamps for illumination of public areaways. This step meant months of experimentation and investigation into the field, for little was known about fluorescent lighting under these conditions except its defects. Fluorescent lighting has so far proved highly successful and has been called better than any other existing system of subway illumination.

Ventilation is another outstanding feature of the new subway. A combination of the piston action method, which relies upon the movement of the trains through the tubes, and the forced draft method was used. The combined capacities of the two systems is 3,000,000 cubic feet of air per minute.

With the construction of this modern subway, science and technology have taken another step forward in the development of underground structures. Building a subway is an immense task, but it is well worth the labor by its simplification of the transportation problem.



REPAIRING DAMAGED LINKS IN OUR LIFELINES

WITHOUT benefit of ceremonies, American ship repair yards are regularly performing one of the most gigantic and least publicized jobs of the war . . . a task which is vital to maintaining a constant flow of troops and materials over our trans-oceanic highways. As evidence of the scope of this achievement, in 1942 alone American shipyards completed repairs on over 12,000 ships of all sizes.

In this big war job, as in the huge ship construction program, the oxyacetylene flame and the electric arc are indispensable. These speedy modern tools provide the fastest and most flexible method of cutting and joining heavy steel ship plates . . . whether it be for production, maintenance or repair. Similarly in many other vital war industries, the oxyacetylene flame and electric arc have made possible unprecedented production records. Their proven speed, efficiency and versatility in war production foreshadows their increased importance in future peacetime manufacturing.

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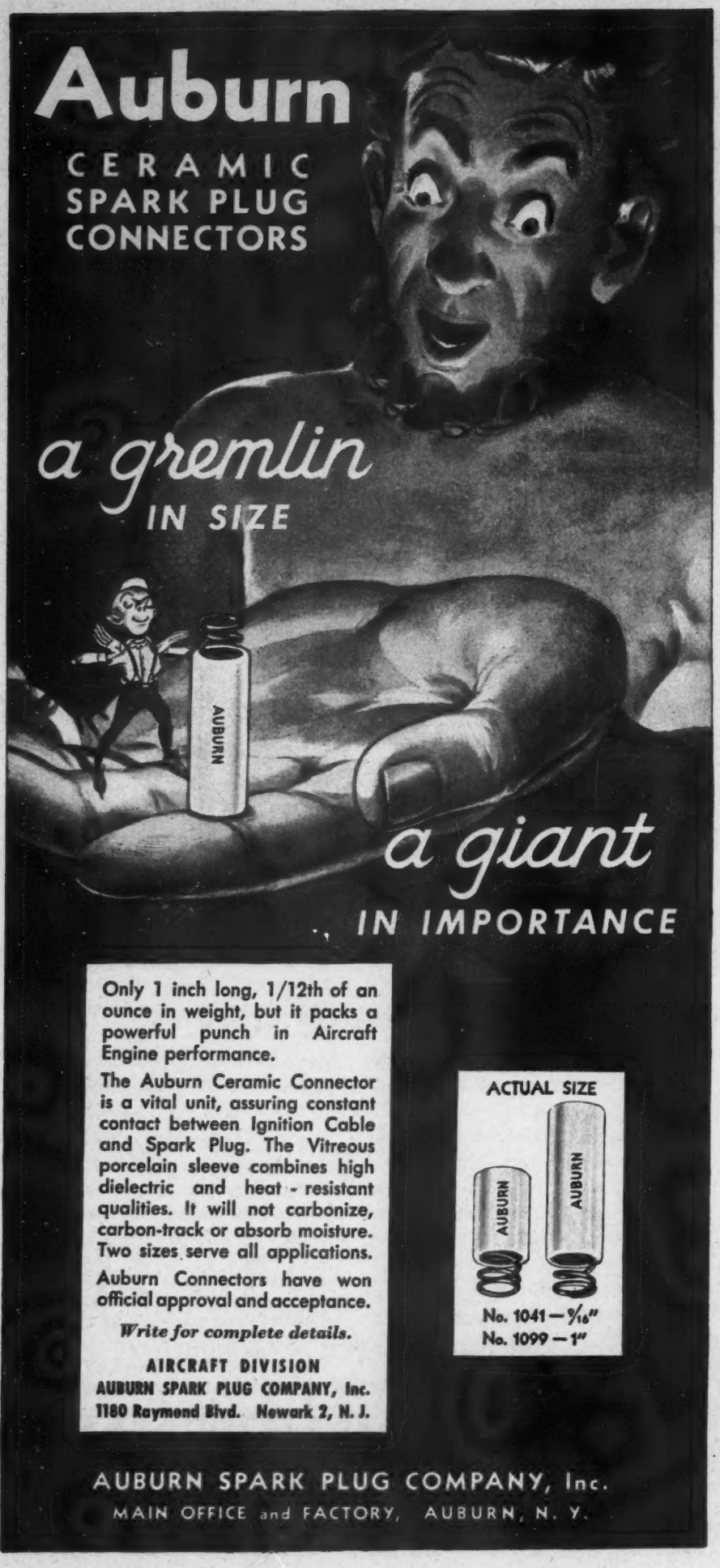
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CYCLES, CODES, AND COPIES

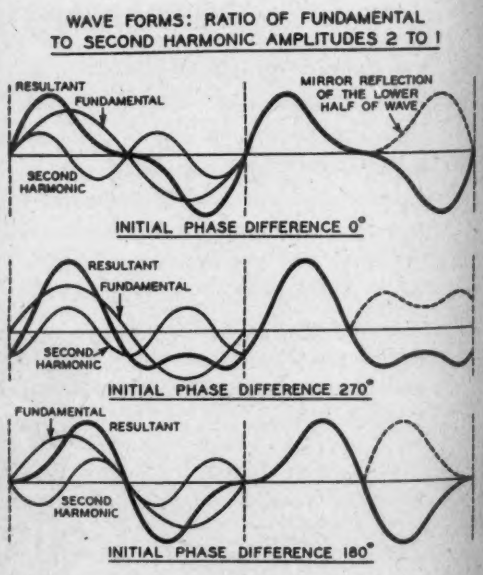
(*Continued from page 183*)

One hundred telephone words of today bear more information than the same 100 words did in 1915.

For the vowels and naturalness and recognition of voice, the lower frequencies, perhaps from 200 up to 1,000 or 1,500 within the band of 3,000, are especially needed. For the consonants, particularly the sibilants like "s," "f," "t," the higher frequencies are needed in the 2,000 to 3,000 range. These sibilant sounds are, in fact, a bit of noise and have no individually human quality in them. They sound the same, no matter what person makes them. But they are very necessary for crispness of words, for identity of words not voices, for articulation, for understandability of words as words. Consonants are the "quips" and "quirks" which in large measure begin and end words. The letter "s," a bit of noise without human or vocal quality, is the initial letter in more English words than any other letter. The letter "s" has more pages in the dictionary than any other letter. The letter "c" is sounded as an "s" oftentimes, too, so the sound of "s" is a very common sound. It is harsh, it is unpleasant, but it does make for clearness of words as words. A wide group of electric waves therefore must be transmitted for the many aspects of human speech in facsimile form.

(*Continued on page 208*)

Figure 6



Sand in Adolf's eye...

THIS man is a glass chemist. And the sand he's working with is going to get into Adolf Hitler's eyes and hurt.

Here's how. Glass, basically is made from sand. And glass in this war, in the skilled hands of American glass makers, is a potent weapon. It replaces metals on many jobs, metals needed for killing Huns and Japs.

In bombsights and fire control instruments glass helps to rain accurate death on the enemy. In heavy industries, such as the explosive industry, its characteristic resistance to corrosion speeds powder output. Glass in medical and laboratory fields puts us and our allies ahead in hospital treatment and in vital laboratory developments.

The U.S. is lucky in having a well established glass industry and not having to lean upon any part of the outside world for this essential material. Glass was ready for war, and was able to contribute to the speed records set by other industries such as gasoline and synthetic rubber.

It took a lot of research to make American glass the best in the world. At Corning way back in peacetime, more than 200 laboratory men were working steadily on new forms of glass and new uses for this amazing material. More than 25,000 formulae for glass were developed. Today around 250 different types of glass are in production under the "E" pennant at Corning's main plant.

There are glasses for example that withstand corrosive chemicals, that cannot be harmed by heat, that have high electrical insulating qualities, that are extremely resistant to mechanical breakage. And these are only a few of the reasons that engineers, too, consider glass the material with endless possibilities for the future. Corning Glass Works, Corning, New York.

CORNING
means
Research in Glass

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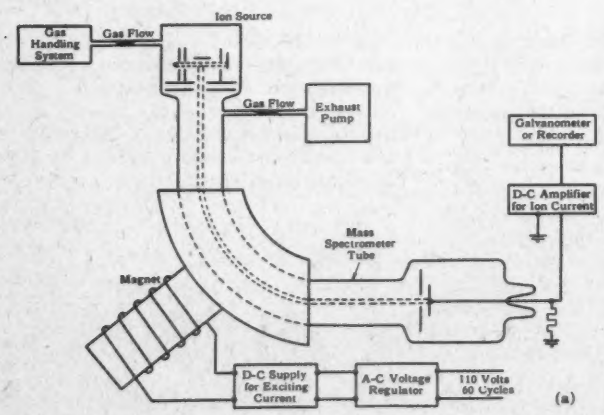
THE ELECTRON TURNS CHEMIST

(Continued from page 189)

As is seen from Figure 4, all gas molecules do not break down into elemental ions. This is especially true of long hydrocarbons such as normal butane, whose autograph is illustrated. In the ionization of normal butane almost every ion between *C H* and *C* is formed as is illustrated by the part of the spectrum shown, the decrease of each mass being due to the loss of a hydrogen atom from the next higher ion. All gases behave somewhat in this manner and the autograph shows the relative amount of each ion in the original gas sample.

Figure 5. General schematic diagram of the elements of the mass spectrometer



A molecule of gas that will dissociate and ionize in one way under one ionizing potential may dissociate and ionize differently under another potential. This dissociation and ionization is therefore a function of the ionizing potential and also offers the principal means of analysis.

If the ratio of $\frac{m}{q}$ is the same for two different ions, it can be seen from Equation 3 that the radii of curvature of the two ion beams will be the same, so that both ions are focused at the same time. This rarely happens, and when it does, the two ions are usually elemental and of the same element. For example, O_2^{++} and O^+ both indicate a mass of sixteen. The ionizing potentials are different for the two ions, however, and we can tell which ion is in focus by its ionizing potential.

The electron and ion accelerating potentials are around one hundred and one thousand volts respectively, and, as the currents through the filament and magnet must be direct and unvarying, the incoming power must be carefully rectified and controlled.

The mass spectrometer is, therefore, a great step forward in chemistry and the chemical industry. Formerly, when analyses were made by hand, in testing a gas used in the production of rubber or gasolene or plastics, the batch would be finished before the tests were completed, and, if the tests turned out badly, the batch was faulty and had to be discarded. Now analyses have been so greatly speeded up that the course to be followed can be guided by them. It is hoped that at some time in the near future a mass spectrometer can be placed in the production line of a gas and used as a continuous control.

The more you give
RED CROSS
The more will live!

THE CO-OPERATIVE COURSE IN ELECTRICAL ENGINEERING

(Continued from page 180)

industry lies not only in his learning how physical laws and theories are applied in practice but also in his learning how to conduct himself in his dealings with his fellow workers and supervisors. Such contacts acquaint him with the everyday applications of his studies in psychology, human relations, business law, and organization. It humanizes his humanistic studies as no amount of book learning can do. It fits him earlier to assume positions of responsibility, where judgment and the knowledge of how to handle men are important. Furthermore, he does not have to learn from costly experiences after he is out of college, that in engineering, every equation always has a dollar sign attached to it, and always contains a term representing the human element — two vital quantities often neglected in practice problems solved at school. The result is — when he graduates he fits into modern industry, knows his way around and becomes immediately productive.

Cover picture courtesy General Electric
Title page picture courtesy Bethlehem Steel Co.
Frontispiece courtesy Universal Studios

Hands that Command the Nation

THE TECHNICAL KNOWLEDGE, the ingenuity and the resources of America are at the disposal of our skilled medical officers on the fighting fronts of the world. They command every aid the nation can supply. That is one reason why a wounded man's chances of survival are greater today than they have been in any other war.

Among the materials that are helping medical men in their fight to save lives are the *stainless steels*. Used in operating tables, surgical instruments and in other medical equipment, stainless steels are serving in hospitals in this country and overseas.

Frequent sterilization with high temperature steam or strong disinfectants will not injure stainless steels. Their smooth, hard surface is easily kept free from germs that can cause fatal infection. Even in the damp tropics, stainless steels do not rust. Tough and durable, free from the possibility of chipping, stainless steels can withstand the rigors of wartime use.

On the home front, too, stainless steels are making their contribution to the health of the nation. Because they are easier to clean and keep clean than other metals, they are widely used in equipment necessary to the processing, preparing and serving of foods. They keep their bright finish, impart no flavor to food, and resist food chemicals. They will be used increasingly in restaurants, in the home, and in many industries where their unique properties are so desirable.

Stainless steels are "stainless" because they contain more than 12 per cent chromium. Low-carbon ferrochromium, a research development of ELECTRO METALLURGICAL COMPANY, a Unit of UCC, is the essential ingredient in the large-scale production of stainless steel. Units of UCC do not make steel of any kind. They do make available to steelmakers many alloys which, like ferrochromium, improve the quality of steel. The basic research of these Units means useful new metallurgical information—and better metals to supply the needs and improve the welfare of mankind.

▼

Members of the medical profession, architects and designers are invited to send for booklet P-3, "THE USE OF STAINLESS STEELS IN HOSPITALS." *There is no obligation.*

CARBON FOR HEALTH. Research by a UCC Unit has resulted in different forms of carbon used in milk irradiators, "sun" lamps, gas masks—and in air conditioning installations.

GASES FOR HEALTH. LINDE oxygen U.S.P. made by a Unit of UCC is used by the sick in hospitals and at home—and it contributes to the safety of our high flying aviators.

CHEMICALS FOR HEALTH. Synthetic organic chemicals, developed by a Unit of UCC, mean better anesthetics, more plentiful sulfa drugs, vitamins and other pharmaceuticals.

PLASTICS FOR HEALTH. BAKELITE and VINYLITE plastics, produced by UCC Units, mean sanitary paints, floor coverings, sheeting, "burn sleeves" and other essentials.

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Johnny, Get Your Gun!

Before John Murdock convinced skeptical Londoners of 1815 that his new discovery, coal gas, was a fuel and not a conjurer's trick, he had to find pipe that would convey the gas safely. Pipe of available materials such as lead, wood and clay either leaked, broke or fouled chemically. Finally, John tried a gun barrel. It worked! If one gun barrel was good, a mile of them would be perfect! So reasoned Murdock, as he spliced and, by heat and hammer, welded all the gun barrels he could buy, borrow or beg, into the world's first steel pipeline. Those gun barrels were the beginning of the present network of little and big inch steel pipelines and safety cylinders and carriers which transport liquid and gas fuel everywhere.

For nearly a century, The Harrisburg Steel Corporation has been known among oil and gas industries for seamless steel products which must meet exacting demands with excellent service and perfect safety. Some of these oil and gas products are seamless steel pipe couplings, pump liners, hollow and drop forgings and pipe flanges. Harrisburg also manufactures seamless steel high pressure cylinders, and liquefiers, alloy and carbon steel, coils and bends. Every "Harrisburg" product conforms with the highest standards in test and inspection.

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(*Continued from page 204*)

Whispered speech is very articulate, sharp, crisp, and by it understandability of words as words is readily conveyed. Whispers are made entirely of noise. The breath is blown between teeth or between teeth and tongue, among other ways. Sheer strident noise is the result. The vocal cords are not involved. Vocal cords give naturalness, pleasantness, and identity of voice. Whispered sounds have no naturalness, no pleasantness. All folks whisper practically alike. Whispers carry information as to meaning of words. Whispers cannot be changed in pitch, and cannot be inflected. Whispers lack the many valuable bits of information in vocal cord sounds. The whisperer cannot be identified by his whisper. He may speak clearly, but one does not know who is the whisperer.

Human speech transmitted with only a low-frequency complement of cycles per second would be natural and pleasant. One would have difficulty to know what was being said, however. Human speech transmitted with only a high-frequency complement of cycles per second would be crisp, clear and understandable. One would have difficulty to know who was doing the talking, however.

Both telephony and telegraphy play an important and particular role in business and social life, on the home front and on the war front. If the job is to send words, sheer words, facts, reports and statistics calling for no inflection, reality or naturalness, the various telegraph systems can send more of this type of information in less time and with narrower ranges of frequencies than can facsimile voice systems. Naturalness of voice, reality and humanness are types of information and must have an appropriate gamut of frequencies.

(*To be continued*)

EDITOR'S NOTE: *This is the first installment of an article on the effects of frequency range on information, by Dr. Perrine. Watch for the descriptions of television, noise, and the nature of sound appearing next month in the conclusion.*

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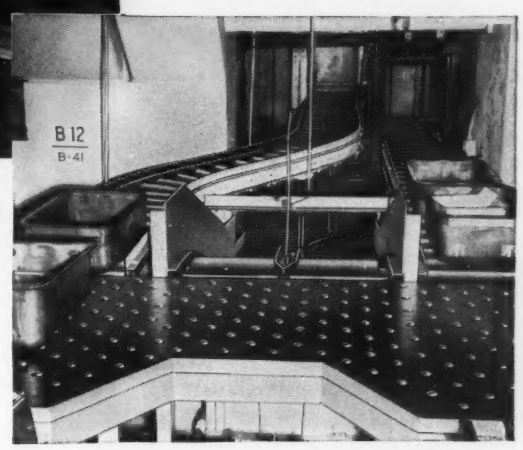

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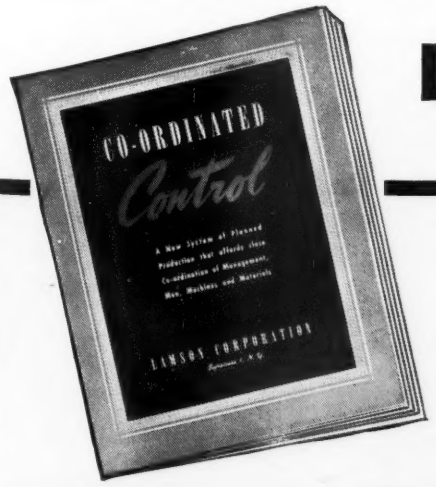
Lamson manufactures both conveyors and dispatch tubes — but more than that, Lamson is an organization of materials-handling engineers, well qualified, by experience, to aid in blue printing postwar production. They have prepared a booklet containing many valuable suggestions. You are sure to profit by its timely information . . . Send for it by filling in the coupon below.



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GE Campus News

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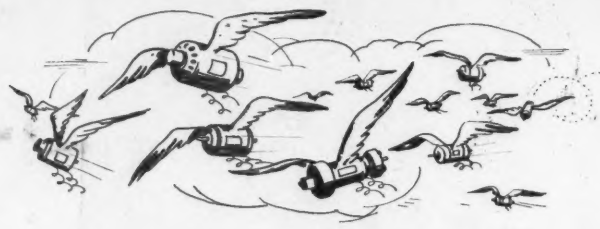
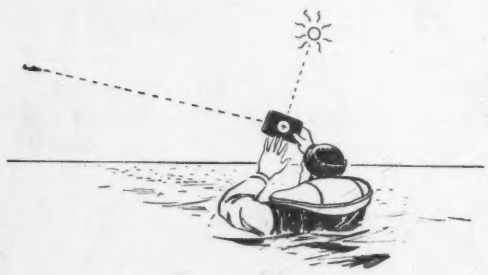


FLYING FAMILY

WHEN a big bomber or a punchy fighter thunders off the field to keep a date high over an enemy target several hundred miles away, many electric motors go along with it—but not just for the ride.

From the time the starting motors turn over the cold engines till, back over the home field, a combat-weary man presses a button and the retractable landing gear lowers from the plane's belly, electric motors are doing hard, exacting work.

These motors, seemingly delivering power out of proportion to their lightness, have taken over most of the tiring muscular jobs . . . like lifting and lowering the flaps against tremendous and varying wind pressures . . . like swinging around the gun turrets at the gunner's slightest signal. And thousands of these are G-E motors, being supplied in ever-increasing numbers for armament operation and for the actuating parts of planes.



SOLAR SEARCHLIGHT

WHEN a dazzling point of light gleams on the broad seascape, and when suddenly that point becomes a blinding glare that persists in following your plane, chances are a man is adrift at sea and needs your help.

He is using one of the new emergency signaling mirrors, designed by General Electric in co-operation with the Coast Guard, the Bureau of Standards, and the National Inventors' Council.

These mirrors are already aboard hundreds of lifeboats and rafts. The shipwrecked sailor follows three simple steps, printed in large letters on the back of the mirror, to shoot a beam of sun-glare at a target—and that target may be a plane or ship up to ten miles away.

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